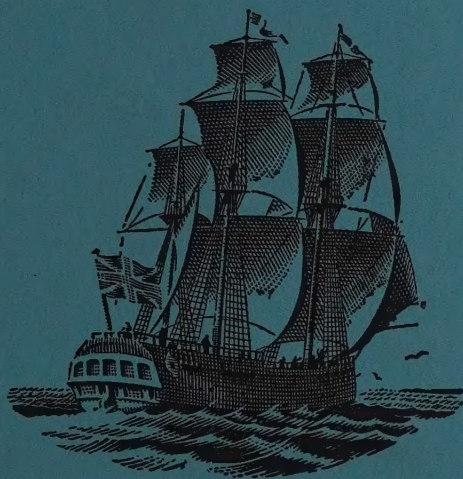# ENDEAVOUR

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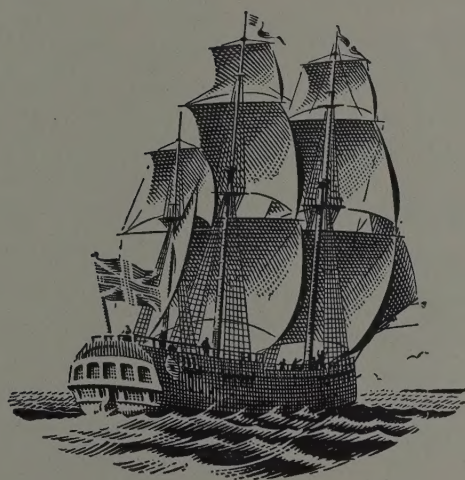
OCTOBER 1953

ENDEAVOUR

The British quarterly scientific journal ENDEAVOUR was first published, by Imperial Chemical Industries Limited, in January 1942. Its purpose is to provide scientists, especially those overseas, with news of the progress of the sciences. While emphasis is laid upon British work, narrow insularity is avoided by publishing numerous articles from overseas contributors and by impartial reference to the world's scientific literature. To make the journal truly international in character it is published in five separate editions—English, French, German, Italian, and Spanish.

No charge is made for ENDEAVOUR. It is distributed to senior scientists, scientific institutions, and libraries throughout the world, the guiding principle being that of helping scientists overseas to maintain those contacts which their British colleagues have always so much valued. Within these limits the Editors are at all times glad to consider the addition of new names to the mailing list.

The drawing on the cover is of the bark Endeavour, *which, commanded by Captain James Cook and carrying a number of scientific workers, was sent out by the British Admiralty in 1768 to chart the South Pacific Ocean and observe the transit of Venus*

ENDEAVOUR

A quarterly review designed to record the progress
of the sciences in the service of mankind

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ALPHABETICAL KEY

ENDEAVOUR

A quarterly review designed to record the
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CONTENTS

A stereochemical centenary

There have lately been several reminders that stereochemistry has now entered upon its second century of existence. First came the centenary of Pasteur's discovery (1848) of the spontaneous resolution of sodium ammonium racemate; secondly, there was the celebration in 1952 of the centenary of van 't Hoff's birth; and now, in 1953, comes the centenary of Pasteur's first use of optically active bases in the resolution of racemic acid.[1] Of Pasteur's three fundamental methods of optical resolution, this second one, dependent originally upon salt-formation with optically active bases or acids, has proved to possess by far the greatest practical importance. For many years after its discovery, this method could still be correctly described as the salt-formation method, as it depended upon the physical process of separating two diastereoisomeric salts by fractional crystallization.

The resolving agents were originally restricted to alkaloids, or derived substances, on the one hand, and to (+)-tartaric acid on the other. Both classes of these agents have since been widely enlarged. Ladenburg had carried out a surprising number of resolutions with the sole aid of (+)-tartaric acid, including that of synthetic coniine in 1888, before Marckwald introduced (−)-tartaric acid as a complementary resolving agent in 1896. It then became possible, by using the (−)-acid, to isolate with certainty the second basic enantiomer after the first had been obtained by using the (+)-acid. A striking example of this technique was provided by the preparation of pure (−)- and (+)-adrenaline from the synthetic base in 1908.

A much greater stimulus to the progress of stereochemistry followed upon the introduction by Kipping and Pope, during the last five years of the nineteenth century, of optically active sulphonic acids derived from camphor: of these, the very useful π-acid, or (+)-α-bromocamphor-π-sulphonic acid, became available in 1895. Three years later, Reychler obtained access to the crystalline acid now known as (+)-camphor-10-sulphonic acid. These strong monobasic acids, as well as others of the same general type, proved to be stereochemically stable and capable of forming beautifully crystalline salts with a great variety of organic bases. Their introduction profoundly affected the development of stereochemistry during the next half-century.

In particular, Pope and his fellow labourers in

[1] C.R. Acad. Sci., Paris, **37**, 166, 1853.

this fruitful field reaped a rich harvest. Their early successes in 1899 with pavine, tetrahydroquinaldine, and other bases were accompanied in the same year by the spectacular resolution of benzylphenylallylmethylammonium salts, of the type $NabcdX$, thus showing for the first time that molecular dissymmetry could be associated with an atom other than that of carbon. In the course of the next few years, Pope and his collaborators gave experimental proofs that atoms of tin, sulphur, and selenium could act in a like manner. These achievements marked the greatest advance in stereochemistry since the work of the three great pioneers, Pasteur, Wislicenus, and van 't Hoff.

Pope's results in this field were amplified considerably in later years through the application of Pasteur's second method to suitable compounds. Thus in 1943 Holliman and Mann, using the π-acid, first prepared an optically stable dissymmetric arsonium salt, as the logical sequel to Pope's original resolution of an organic nitrogen compound 44 years earlier. Many other investigations by various workers on optically active organic derivatives of phosphorus, sulphur, selenium, silicon, and other elements have been brought to a successful issue solely through the application of Pasteur's second method.

In 1914 Pope and Read varied the method by introducing the idea of repeated fractional precipitation. This process led to the resolution of chloroiodomethanesulphonic acid,

$$\text{H}-\overset{\displaystyle \text{I}}{\underset{\displaystyle \text{Cl}}{\text{C}}}-\text{SO}_3\text{H},$$
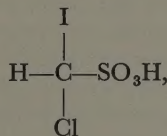
the first optically active substance to be obtained with fewer than three carbon atoms in the molecule, and still the simplest of all known compounds displaying optical activity. Some years later (1925–7), Read and McMath showed that, in general, such simple molecular systems racemize with great ease and sometimes undergo asymmetric induction.

At the time of Pope's early researches, Pasteur's second method was leading to important results in other fields of organic chemistry. In 1899, E. Fischer employed it in bringing about the resolution of the synthetic forms of amino-acids of importance in protein chemistry; by applying brucine and

strychnine in turn to the acylated acids, he was able, in many instances, to isolate the pure $(+)$ and $(-)$ forms. In another important field, Pickard and his collaborators began, in 1904, to devise methods for the resolution of externally compensated alcohols. The most effective of these (1912) depended upon resolving a suitable acid ester (notably the phthalate or succinate) of the alcohol with the aid of active bases.

An earlier method (1904) represented a departure from Pasteur's original procedure, the two diastereoisomeric salts being replaced by two diastereoisomeric carbamic esters. Much later (1931 onwards), the resolution of alcohols, especially in the terpene series, by the use of suitable crystalline esters was developed considerably by Read and his collaborators. Diastereoisomeric condensation products of various kinds have also been successfully used in other extensions of the original method, among them being Schiff's bases (Erlenmeyer jun., 1903), substituted amides (Kipping and Salway, 1904), and condensation products of externally compensated bases with $(+)$- and $(-)$-hydroxymethylenecamphor (Pope and Read, 1909).

An extension of Pasteur's second method, entailing the first departure in fundamental principle from its original form, arose out of a series of investigations originated by Marckwald and McKenzie, who found in 1899 that $(-)$-menthyl-$(+)$-mandelate was formed more rapidly than its diastereoisomer when $(-)$-menthol was heated with an excess of externally compensated mandelic acid. Pasteur's original method was static and physical; this dynamic and chemical modification utilizes the actual chemical reaction as the effective resolving agency. In general, such dynamic methods are of subordinate interest as practical methods.

So far, the review of the great advances in stereochemistry which followed the introduction of Pasteur's second method of optical resolution has been confined to substances containing in the molecule at least one so-called asymmetric atom ($Cabcd$, $NabcdX$, etc.), which gives rise to enantiomerism by reason of its asymmetric tetrahedral environment. However, it was already realized by van 't Hoff, in 1875, that the presence of such an atom in a molecule must be regarded merely as a convenient criterion of the dissymmetry of the whole molecule; further, he postulated the possible existence of dissymmetric molecules containing no particular asymmetric atom, as for example in allenes of the type $abC:C:Ccd$. The validity of this fundamental conception was first proved experimentally in 1909, by Perkin, Pope, and Wallach,

through the resolution with brucine of 1-methyl-*cyclo*hexylidene-4-acetic acid. Pasteur's second method had again led to an achievement of the highest importance in stereochemistry, one which was indeed described in 1940 as 'the basis of all modern stereochemical investigation.' It confirmed the broad view of van 't Hoff that any compound whose molecules have no plane of symmetry can exist in optically active forms.

It was on this broad basis that Alfred Werner developed the stereochemistry of an immense array of co-ordination compounds; these he referred to an octahedral model, the centre of which might be occupied by a variety of metallic atoms, including cobalt, chromium, platinum, iron, and others. He prepared the first optically active compound of this type in 1911, with the aid of the π-acid, in accordance with Pasteur's second method.

Werner's work led to a large expansion of the boundaries of stereochemistry, and enabled him to accomplish the synthesis of a complex inorganic compound which was devoid of carbon and yet exhibited optical activity in solution.

Still another field of stereochemistry based experimentally upon the application of Pasteur's second method is that of dissymmetric molecules owing their optical activity to restricted rotation about a single bond. Arising out of an initial observation made by Christie and Kenner in 1921 upon substituted diphenic acids, this field has widened greatly in later years through the work of Mills, Adams, Turner, and others.

This review of some of the direct consequences of Pasteur's conception of a century ago, although brief, is perhaps sufficient to show that the conception has been one of the chief factors in the vigorous growth of a branch of science which is now seen to permeate the whole vast realm of organic chemistry. Such a development could not have been foreseen, and early workers on stereochemistry had to endure much harsh criticism and even ridicule. Scientists are apt to pride themselves on their freedom from prejudice, so it may be salutary to recall that, concerning the fecund 'tetrahedral' theory, Kolbe wrote thus of van 't Hoff: 'A certain Dr J. H. van 't Hoff, who holds an appointment at the Veterinary College of Utrecht, has, it appears, no taste for exact chemical research. He has thought it easier to bestride Pegasus (probably borrowed from the Veterinary College) and to proclaim in his *La Chimie dans l'Espace* how on his bold flight to the chemical Parnassus the atoms appeared to be arranged in space.' *Autres temps autres mœurs.*

The biological importance of organic compounds of sulphur

FREDERICK CHALLENGER

The great biological significance of sulphur has been appreciated for only some thirty years, but during that time a wealth of information has been acquired. While there are still many gaps in our knowledge, and much must still be done to fit what is already known into a logical and easily understandable pattern, certain fundamental relationships have already become apparent. The principal roles of sulphur in biological systems are here reviewed.

Until about 1922, comparatively little systematic attention was directed to the occurrence of organic compounds of sulphur in nature. The presence of cystine,

$$CO_2H.CH(NH_2).CH_2.S.S.CH_2.CH(NH_2).CO_2H,$$

in the protein keratin, occurring in hair, skin, and nails, was well established, and its biological importance was recognized. The oxidation-reduction 'catalyst' glutathione was discovered by Hopkins in yeast, red blood cells, and animal tissues in 1921, and was finally shown to be a tripeptide, glutamyl-cysteinyl-glycine. Its oxidized form proved to be a derivative of cystine, while its reduced form contained a cysteine,

$$HS.CH_2.CH(NH_2).COOH,$$
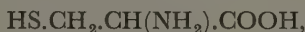
residue. A decided impetus was thereby given to the study of the $R.S.S.R \rightleftharpoons 2RSH$ relationship as exemplified by these two amino-acids.

Apart from studies of this kind, however, research on natural compounds of sulphur had dealt with isothiocyanates, a few sulphides R_2S, disulphides R_2S_2, and mercaptans RSH (where R is an organic group), and with the natural esters of sulphuric acid such as the polysaccharide sulphates of seaweeds and cartilage, and the phenol sulphates which occur in the urine of animals. The characteristic odour and taste of mustard, cress, and many other *Cruciferae* are due to the presence of complex glycosides of aliphatic, and occasionally aromatic, isothiocyanates which, on hydrolysis, often yield a hexose, potassium hydrogen sulphate, and a pungent isothiocyanate. Mustard seeds yield allylisothiocyanate,
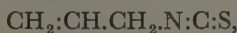
$$CH_2:CH.CH_2.N:C:S,$$

and the garden 'nasturtium' (*Tropaeolaceae*) phenyl-ethylisothiocyanate, $C_6H_5.CH_2.CH_2.N:C:S$. The seeds of wallflowers contain cheirolin,

$$CH_3.SO_2.CH_2.CH_2.CH_2.N:C:S, \text{ and erysolin,}$$
$$CH_3.SO_2.CH_2.CH_2.CH_2.CH_2.N:C:S.$$
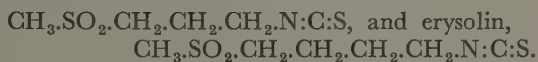
Sulphuric acid plays an important part in the detoxication of normal products of animal metabolism, and of foreign substances other than foodstuffs which may be ingested. Thus in protein metabolism phenol, arising partly from tyrosine, and indoxyl from tryptophan, are both excreted as esters with sulphuric acid: phenyl and indoxyl-sulphuric acids, $C_6H_5.O.SO_2.OH$ and

$$C_6H_4 \begin{matrix} C-O.SO_2.OH \\ \\ CH \\ \\ NH \end{matrix} \quad .$$
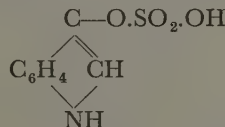
The most plentiful phenolsulphate in human urine is *p*-cresolsulphuric acid, which is also found in large quantities in the urine of horses; in the case of the stallion the aromatic ring may arise from oestrone as well as from tyrosine. Naphthalene and bromobenzene administered to animals are hydroxylated and excreted as the potassium salts of the α-naphthol and the *p*-bromophenolsulphuric acids respectively. The formation of phenolsulphuric acids in animals has been discussed by R. T. Williams [1].

In 1923 Mueller isolated a new amino-acid, methionine, from the products of the hydrolysis of wool, egg-albumen, or casein [2]. Its structure, $CH_3.S.CH_2.CH_2.CH(NH_2).COOH$, was determined by Barger and Coyne [3], who synthesized it in 1928. Barger remarked that his belief in the correctness of this formula was greatly strengthened by its close analogy with the structure of cheirolin, both compounds containing the same C.S.C.C.N

chain. Earlier workers had already emphasized the fact that many natural amino-acids have their counterpart, as regards chain-length, among the natural isothiocyanates, and that a generic relation almost certainly exists between them, e.g. $C_6H_5.CH_2.CH(NH_2).COOH$ (phenylalanine) and $C_6H_5.CH_2.CH_2.N:C:S$. The occurrence of erysolin, a homologue of cheirolin, in wallflower seeds suggests that homomethionine may ultimately be found in nature. Sulphoraphene (see p. 178) and the corresponding nitrile have recently been isolated from radishes, and have the C—S—C chain of homomethionine. We shall see later that methionine may be regarded as the parent substance of several other natural products, or of compounds derived from natural sources by treatment with reagents. It thus occupies a dominating position in the biochemistry of sulphur.

METHYLATION BY ANIMALS

The recognition of methionine as an ingredient of protein led to an intensive study of its properties, particularly in relation to animal growth and biological methylation. In this connection, du Vigneaud and his colleagues at the Medical School of Cornell University have been responsible for much work of outstanding interest; it has been discussed in several reviews [4], and is most attractively summarized under the title 'A Trail of Research' by du Vigneaud [5] in his Messenger Lectures for 1950, where the development of the work is carefully described from the historical aspect.

It was found by earlier workers that methionine is essential for the growth of rats, and that, like choline, it is also capable of restoring normal conditions in animals which, on a diet deficient in choline, develop the pathological conditions known as fatty liver and haemorrhagic kidneys. Certain compounds not containing a methyl group, e.g. the triethyl analogue of choline, also cure this condition, and the effect appears to be due to the provision or formation of choline or analogous substances. Nevertheless, the study of these two pathological conditions influenced the development of the conception of the mobile methyl group, which had first been postulated in general terms by Hofmeister [6] during his studies on the volatilization of tellurium by animals. This he believed (no doubt correctly, though it has never been proved) to be due to the formation of dimethyl telluride. He considered that the tissues which possess the capacity for methylation already contain the methyl group as such. In the presence of pyridine or tellurium compounds, these substances would undergo methylation, whereas normally other methyl compounds, e.g. choline and creatine derivatives, are formed. He did not specifically mention choline or betaine as sources of the methyl group. Riesser [7] in 1913, however, suggested that these compounds might lose a methyl group, which could appear in creatine and in the volatile alkylated (presumably methylated) derivatives of selenium and tellurium which are evolved on administration of compounds of these elements to men and animals. He adduced some purely chemical experiments in support of his views, and showed that, on heating sodium tellurite or selenite with sodium formate and salts of choline or betaine, odours resembling those of dimethyl selenide and telluride were produced, but no chemical identification was carried out. Riesser's work was extended by the author and Constance Higginbottom [8] to include sulphite, and the dimethyl sulphide, selenide, and telluride formed by the transfer of the methyl groups were conclusively identified.

This conception of transmethylation from a methyl reservoir or a methyl donor was employed by du Vigneaud in his studies of methylation processes in animals, and by the author as one of the guiding hypotheses in attempts to elucidate the mechanism of mycological methylation. In du Vigneaud's now classical experiments [5] of 1939, it was shown that young white rats which failed to grow on a diet free from choline or methionine but containing the demethylated derivative homocystine,

$$(COOH.CH(NH_2).CH_2.CH_2.S)_2$$
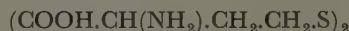
developed normally when choline,

$$(CH_3)_3\overset{+}{N}(\overset{-}{OH}).CH_2.CH_2.OH,$$
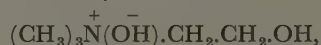
was added to the diet. This was explained on the assumption of the transfer (transmethylation) of a methyl group from choline to homocysteine (the thiol form, RSH, of homocystine, R.S.S.R) thus generating methionine and so enabling growth to proceed. This assumption was proved correct by feeding the rats with methionine containing deuterium in the methyl group, when the choline and creatine of the tissues and the creatine of the urine (see p. 176) were found to possess a very high percentage of deuterium in their methyl groups— 85 per cent. of that theoretically possible. That the methyl group was transferred as an entity followed from the fact that the deuterium ratio (85) was much higher than the maximum (66·7) which

could be reached if oxidative elimination of CD_2O, ultimately yielding

$$[(CD_2H)_3N.CH_2.CH_2.OH]^+OH^-,$$
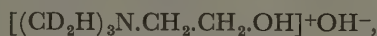
had occurred. Later, du Vigneaud extended the feeding with methionine to three months and obtained a deuterium ratio of 90. The reaction is reversible; deuteriocholine when administered to a rat gave deuteriocreatine as before, and also deuteriomethionine, which was isolated. Thus methionine, choline, and, later, betaine,

$$(CH_3)_3\overset{+}{N}.CH_2.CO.\overset{-}{O},$$

were shown each to possess a mobile methyl group. By using methionine, it was shown that the labelled methyl group can be detected in creatine, anserine, betaine, and adrenaline, using such varied organisms as man, rabbit, rat, or wheat-seedlings, methyl being transferred from sulphur to nitrogen. Recently it has been shown [9] that methionine can furnish the methyl of the methoxy groups of lignin when added to well-grown barley-seedlings. This is probably the first observation which has been made of transmethylation from sulphur to oxygen.

Parts of this work, and most of the later experiments on transmethylation, have been carried out with methionine labelled with the radioactive isotope C^{14}. By the use of a mixture of deuterio-L-methionine and C^{14}-L-methionine it has been shown that the ratio $D : C^{14}$ in the methyl groups of the choline and creatine was the same as in the isotopic methionine administered. This affords a final demonstration of the correctness of the hypothesis of transmethylation.

METHYLATION BY MOULDS

It was stated above that transmethylation was considered as a possible explanation of the methylation exhibited by certain moulds, especially *Scopulariopsis brevicaulis, Aspergillus niger*, and *Penicillium notatum*. Cultures of *S. brevicaulis* convert arsenious oxide, sodium selenate or selenite, sodium tellurite, and dialkyl disulphides to trimethylarsine, dimethyl selenide, $(CH_3)_2Se$, dimethyl telluride, $(CH_3)_2Te$, and alkyl mercaptan and alkyl methyl sulphide respectively. The wood-destroying fungus *Schizophyllum commune*, unlike the moulds just mentioned, can convert inorganic sulphate to methyl mercaptan and dimethyl sulphide [13, 14]. Assuming that the process was a transmethylation, several intermediate stages were postulated, involving the elimination of a methyl group from a

donor as a positive, or possibly a neutral, radical which was captured by the unshared electrons of the inorganic ion, e.g. $:\bar{A}sO_3H_2$, $:\bar{S}eO_3H$ or of $C_nH_{2n+1}.\bar{S}—$, giving as the first intermediate stage $CH_3AsO_3H_2$ or CH_3SeO_3H, which by reduction and further methylation could finally yield trimethylarsine and dimethyl selenide. An account of the work in this field by the author and his students since 1931 has been described in several reviews, where the experimental work devised to test the various hypotheses is fully discussed [4].

During the last two years, D. B. Lisle in the author's laboratory has studied the behaviour of choline, betaine, and methionine labelled in one methyl group with C^{14}, and also of sodium formate $H.C^{14}OONa$, in bread cultures of *S. brevicaulis* and of *A. niger* containing arsenious acid or sodium selenate. It has been firmly established by the recent work of Sakami in America and of Arnstein in Britain that, in the rat, the formate carbon atom can act as a source of methyl and ultimately appears in the choline of the tissues. Other one-carbon fragments detached from glycine, serine, and acetone can act in a similar manner, thus furnishing an alternative route to that of transmethylation, though this may be involved in the final stage. In Lisle's experiments the trimethylarsine and dimethyl selenide were absorbed in acidified mercuric chloride as usual, and the activity of the precipitated addition-product was measured and compared with that of the radioactive compound added to the cultures. The amount of $C^{14}H_3$ in the precipitates was expressed as a percentage of that which would have been obtained had the whole of the methyl groups been derived from the one millimole of added methyl donor or source.

With *S. brevicaulis*, the percentages for trimethylarsine formation were: choline chloride, 1·9; betaine, 0·7; sodium formate (5 millimoles), 3·1; and DL-methionine, 28·3. For dimethyl selenide formation the corresponding figures were 1·2, 1·2, 4·4, and 25·5. Using *A. niger* and 5 millimoles of methyl source in each case the percentages were: choline chloride, 1·0; betaine, 5·3; sodium formate, 2·0; and DL-methionine, 44·0. Using cultures of *A. niger* on liquid media, the figure for methionine has been raised to 90. These experiments suggest that not only is methionine a methyl donor in mycological methylation but that it is probably concerned with the later stages, and possibly the final stage, in the transmethylation. Choline, betaine, and formate may first give rise to methionine before the final transfer of methyl occurs. It may be mentioned that choline must

first be oxidized to betaine before transmethylation in certain animal enzyme preparations can occur [10]. Moreover, choline does not methylate guanidoacetic acid to creatine in surviving liver tissue unless homocystine is also present [11a].

$$\begin{array}{cc} NH_2 & NH_2 \\ >C = NH & >C=NH \\ H.N.CH_2.COOH & CH_3.N.CH_2.COOH \\ \textit{Guanidoacetic acid} & \textit{Creatine} \end{array}$$

$$\begin{array}{c} NH—CO \\ | \quad\quad | \\ C=NH \\ | \\ CH_3.N——CH_2 \\ \textit{Creatinine} \end{array}$$

It would therefore be expected that, in presence of DL-homocystine, formate and betaine would be more effective in transmethylation experiments in mould cultures, since the DL-homocysteine resulting from reductive fission of homocystine would probably undergo ready methylation to methionine. Preliminary experiments by P. B. Dransfield confirm this expectation, the transmethylation being two to four times as great as in absence of homocystine.

It had been suggested that, before the transfer of its methyl group, methionine may be converted to a quaternary compound, but conclusive evidence of this change was lacking. Recently, however, Cantoni [11b] has reported that in an enzyme preparation obtained from rabbit liver and containing adenosine triphosphate, methionine yields orthophosphoric acid and an 'active' methionine which he regards as responsible for the methyl transfer. To this he assigns the quaternary structure

$$\begin{array}{c} N—C.NH_2 \\ \| \quad \| \\ CH \ C—N=CH \quad\quad O \\ | \quad | \\ N=C—N—CH.CHOH.CHOH.CH \\ \bar{O}.OC.(NH_2)CH.CH_2.CH_2.\overset{+}{S}.CH_2 \\ | \\ CH_3 \end{array}$$

containing the S-adenosylmethionine ion. This compound has been separated by paper chromatography, and the presence of the adenyl residue was established spectroscopically. A colour-reaction with orcinol, and the formation of creatine, indicate the presence of a pentose and a mobile methyl group. Acid hydrolysis yields adenine with,

apparently, homoserine and a thioribose or methylthioribose. This explains the importance of adenosine triphosphate in biological methylation, and affords a most interesting link with adenylthiomethylpentose, $C_5H_4N_5.C_4H_6O_3.CH_2.S.CH_3$, previously isolated from yeast and now seen to be related to methionine. The occurrence of S-adenosyl homocysteine,

$$C_5H_4N_5.C_4H_6O_3.CH_2.S.(CH_2)_2.CH(NH_2).CO_2H$$

in nature is therefore not unlikely.

FISSION AND METHYLATION OF THE MONO- AND DI-SULPHIDE LINKS

It should be mentioned that *S. brevicaulis* does not produce dimethyl sulphide from inorganic sulphate. Numerous other compounds of sulphur, both inorganic and organic, have been tested, but no volatile methyl derivative was evolved. The occurrence of methionine and cheirolin in nature, and their structural relations to cysteine and cystine, suggested that compounds containing the —SH or —S.S— links might be more amenable to the methylating action of certain moulds. This expectation was found to be justified [12].

Dialkyl disulphides (methyl to *n*-amyl) were added in dilute sterile aqueous suspension to the bread cultures. The volatile products contained the alkylthiol, R.SH, the unchanged disulphide, R.S.S.R, and the methyl alkyl sulphide, R.S.CH₃. Diallyl disulphide behaved in a similar manner, and, in view of the occurrence of this disulphide in garlic (*Allium sativum*), methyl allyl sulphide may yet be discovered in the *Cruciferae*. The fission of the disulphide link by *S. brevicaulis* appears to be a general reaction of simple aliphatic disulphides. It is of interest that *n*-butanethiol occurs in the secretion of the skunk; isopentanethiols and traces of methanethiol are also stated to be present.

By the use of the same radioactive methyl sources as before in bread cultures of *S. brevicaulis* containing diethyl disulphide, Dransfield has shown that the ethanethiol (separated as the mercaptide, $(C_2H_5S)_2Hg$) was not radioactive—as would be expected—but that the methyl ethyl sulphide mercurichloride was active. The percentages of $C^{14}H_3$ in this sulphide, derived from the added methyl sources, were approximately the same as in the experiments where arsenious oxide and sodium selenate were used. As in the animal experiments of du Vigneaud and his school with C^{14}-methionine, considerable oxidation of the labelled carbon atom to carbon dioxide occurred with all these substrates.

The work on the fission of the disulphide link by *S. brevicaulis* [12] was followed by the observation that the same mould can cause the fission of the link between sulphur and carbon. In an attempt to determine the mechanism of the formation of methanethiol from inorganic sulphate in cultures of *Schizophyllum commune* [13, 14], the behaviour of DL-methionine in cultures of this fungus was examined. No appreciable quantity of methanethiol was evolved, but on addition of methionine to bread cultures of *S. brevicaulis* the amino-acid readily gave methanethiol and dimethyl sulphide. Fission and methylation had therefore occurred. Under identical conditions S-methyl, S-ethyl, and S-*n*-propyl-cysteine,

$$RS.CH_2.CH(NH_2).COOH,$$

gave the corresponding alkanethiol and methyl alkyl sulphide. The fission of the C—S link appears to be a new type of mycological action. It is not clear whether the reaction is reductive or hydrolytic [14].

This fission has two interesting counterparts in animal biochemistry. The unsymmetrical amino-acid cystathionine,

$$HO_2C.CH(NH_2).CH_2.S.(CH_2)_2.CH(NH_2).CO_2H$$
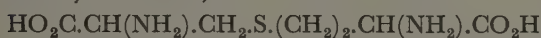
in the presence of rat liver, or kidney slices, or saline extracts of rat liver, gives cystine. Cystathionine plays an important part in the biological conversion of methionine to cysteine and thence to cystine and, as has been shown by isotopic studies, yields cysteine by fission of the monosulphide link, the shorter carbon chain remaining attached to sulphur. The cystathionine probably arises from methionine by demethylation to homocysteine, followed by condensation with serine,

$$HO.CH_2.CH(NH_2).COOH.$$

An account of the work leading to this discovery is given by du Vigneaud [5].

Some years later, Binkley [15] obtained results with the enzyme thionase, obtained from animal tissues, which are analogous to those of the author and Charlton with the alkylcysteines. Preparations of the purified enzyme, activated with glutathione, convert S-alkylcysteines (methyl to butyl) to the corresponding thiols. The S-carboxymethyl and S-carboxyethyl derivatives slowly yield thioacetic acid and β-thiopropionic acids,

$$HS.CH_2.COOH \text{ and } HS.CH_2.CH_2.COOH.$$
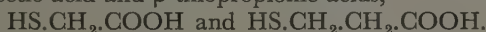
LANTHIONINE

Another amino-acid containing sulphur is lanthionine,

$$HO_2C.CH(NH_2).CH_2.S.CH_2.CH(NH_2).CO_2H,$$
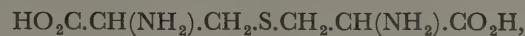
which was first obtained by the action of aqueous sodium carbonate on wool [16], and later from other proteins such as hair by the same process. It contains one atom of sulphur less than cystine, but clearly could not arise by simple removal of sulphur from the middle of the cystine chain. Presumably the first stage in its formation is the hydrolytic fission of cystine, giving

(*a*) $HOOC.CH(NH_2).CH_2.SH$ and
(*b*) $HOOC.CH(NH_2).CH_2.S.OH.$
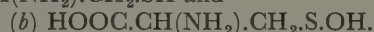
The cysteine might then react with (i) serine $CH_2OH.CH(NH_2).COOH$ in the wool protein (or possibly arising from (*b*) by loss of sulphur) with elimination of a molecule of water, or (ii) with α-aminoacrylic acid $HOOC.C(NH_2) = CH_2$, which could be regarded as arising from serine or alanine by dehydration or dehydrogenation respectively. Serine has recently been shown to have considerable importance in animal biochemistry. The second type of reaction (ii) can be realized in the laboratory; α-acetylamino-acrylic acid and cysteine react in slightly alkaline solution to give the acetyl derivative of lanthionine [36]. In 1946 lanthionine was detected in the tips of virgin wool by paper chromatography after hydrolysis.

No clear evidence of the existence of lanthionine as a major constituent of protein not previously treated with alkali was obtained until some years later. The meso-form of lanthionine has now been isolated from the products of the hydrolysis of the antibiotic peptide subtilin, which is produced by a particular strain of *Bacillus subtilis* [17a]. This peptide contains over 4 per cent. of sulphur, but no disulphide or sulphydryl groups. The lanthionine was separated from the mixture resulting from hydrolysis—which contains no cystine or methionine—by fractionation of the phosphotungstates, or by the method employed by Horn and his colleagues [16]. No alkali was used in the hydrolysis. The lanthionine was identified by the formation of derivatives and by X-ray powder photographs. It appears that the L-isomer of lanthionine, but not the meso-form, undergoes cleavage in the rat to form cystine, as in the case of cystathionine.

It seemed likely that a closer investigation of various natural products might reveal the presence of sulphur compounds not previously identified. A preliminary investigation of the onion [17b] showed that propane-1-thiol, $CH_3.CH_2.CH_2.SH$, is present in the volatile products from freshly chopped bulbs. Propane-1-thiol had not previously been found in nature, although the author and Rawlings

observed its formation from the corresponding disulphide in cultures of *Scopulariopsis brevicaulis* [12].

NATURAL SULPHOXIDES

Stoll and Seebeck [18] have recently shown that the diallyl disulphide of garlic is probably derived from alliin, which can be isolated from the same plant and has been shown to be S-allylcysteine sulphoxide

$$CH_2:CH.CH_2.S.CH_2.CH(NH_2)COOH.$$
$$\downarrow$$
$$O$$
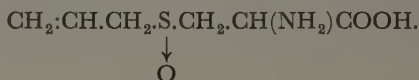
It is believed that this is readily converted to allicin, isolated from garlic by Cavallito [19], which appears to have the structure

$$CH_2:CH.CH_2.S.S.CH_2.CH:CH_2$$
$$\downarrow$$
$$O$$
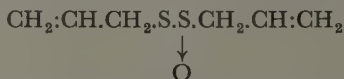
and to be the immediate precursor of the diallyl disulphide. Methionine, through a series of reactions involving cystathionine (see p. 177), might be the precursor of alliin, or it might arise more simply by the interaction of allyl mercaptan and serine, followed by oxidation to the sulphoxide. Allicin and alliin were the first sulphoxides to be detected in a natural product, with the possible exception of 2-hydroxyethyl sulphoxide,

$$(HO.CH_2.CH_2)_2S{\rightarrow}O,$$
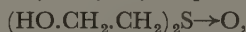
which was isolated from the suprarenals of oxen. Their discovery was soon followed by that of sulphoraphene,

$$CH_3.S.CH:CH.CH_2.CH_2.N:C:S,$$
$$\downarrow$$
$$O$$
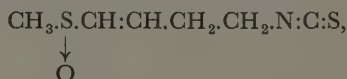
and the corresponding nitrile, which were isolated from radishes by Schmid and Karrer [20]. These two compounds are optically active. They contain no asymmetric carbon atom and are the first example of natural sulphoxides owing their activity solely to the asymmetry of an R′.S.R″ group. Alliin

$$\downarrow$$
$$O$$

contains an asymmetric carbon atom as well as an asymmetric sulphoxide group. The first optically active sulphoxides were prepared and resolved in 1926 by Kenyon and Phillips, and it must have caused considerable satisfaction to these authors that their experimental work was confirmed in this striking manner.

A NATURAL SULPHONIUM COMPOUND

Reference has already been made to the natural sulphones derived from methionine and homomethionine. Recently, Karrer and Eugster [21] have reported the isolation of dimethyl sulphone from various species of *Equisetum* (horsetails), and somewhat earlier Smythe found the same compound in dried ox-blood. The sulphone might be formed by decarboxylation of

$$CH_3.SO_2.CH_2.COOH \text{ or of } SO_2(CH_2.COOH)_2,$$
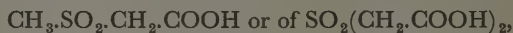
but in view of some work now to be described it may arise by oxidation of dimethyl sulphide, which was shown by Haas [22] to be evolved from the red marine algae *Polysiphonia fastigiata* and *P. nigrescens* on their removal from the sea and exposure to air. The author showed that the sulphide was entirely free from methanethiol, dimethyl disulphide, or any other sulphide. It was interesting to inquire whether the sulphide evolution is an essential metabolic process of the alga or whether it is due to abnormal conditions. When the weed, still attached to its carrier, *Ascophyllum nodosum*, was immersed in a jar of sea-water immediately on removal from the rock-pools, and a stream of air passed through, no sulphide was evolved for at least 24 hours, whereas when it was detached from its carrier and placed in tap, or distilled, water the dimethyl sulphide was detected in a few hours. Grinding with sand on immersion in distilled water facilitated evolution of the sulphide. Immersion in boiling water inhibits liberation of the sulphide when the weed is afterwards exposed to air. The process seems to be enzymatic, and to occur under slightly abnormal conditions. Long boiling with water or treatment with sodium hydroxide gives dimethyl sulphide, presumably by purely chemical hydrolysis of some precursor. The author and Miss Margaret Simpson [23] examined an alcoholic extract of *P. fastigiata* and obtained a crystalline salt, which was identified as dimethyl-2-carboxyethylsulphonium chloride

$$(CH_3)_2\overset{+}{S}(\overset{-}{Cl}).CH_2.CH_2.COOH,$$
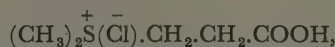
(dimethyl-β-propiothetin chloride, so called from its structural analogy with betaine chloride

$$(CH_3)_3\overset{+}{N}(\overset{-}{Cl}).CH_2.COOH),$$
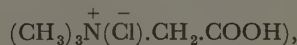
by analysis and by conversion to numerous derivatives which were compared with authentic specimens. This represented the first proof of the occurrence of a sulphonium compound in a plant. The same thetin has recently been isolated from another seaweed, the bright green *Enteromorpha intestinalis*, by R. Bywood. The thetin may possibly be present

in the algae as a peptide or ester, and the anion may be a polysaccharide sulphate ion.

Woolley [37] refers to a report by Shive of the isolation from cabbage of methioninemethylsulphonium chloride

$$(CH_3)_2\overset{+}{S}(\overset{-}{Cl}).CH_2.CH_2.CH(NH_2).CO_2H.$$
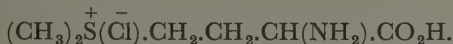
This is the second sulphonium compound to be detected in a plant. The thetin could arise from Shive's sulphonium salt by oxidation, deamination, and decarboxylation. Dransfield, in the author's laboratory, finds that methioninemethylsulphonium chloride, labelled with C^{14} in one methyl group, can furnish 36 per cent. of the methyl groups of the dimethyl selenide evolved from cultures of *Aspergillus niger* containing sodium selenate.

The evolution of dimethyl sulphide from the algae mentioned presents some chemical analogy with the observation of Cromwell [24], that the presence of trimethylamine in the flowers of the stinking goosefoot (*Chenopodium vulvaria*) is due to the action of an enzyme on choline. Betaine, unlike choline, is not attacked by an enzyme preparation of the plant. The occurrence of trimethylamine in the flowers of the hawthorn (*Crataegus oxyacanthoides*) and the cotton plant (*Gossypium barbadense*) may also be due to the breakdown of choline.

When du Vigneaud established the mobility of the methyl group in methionine, choline, and betaine he also showed that dimethylacetothetin chloride $(CH_3)_2\overset{+}{S}(\overset{-}{Cl}).CH_2.COOH$ (which has not yet been found in nature) had a labile methyl group. When the isolation of the homologous thetin from seaweed was announced, Maw and du Vigneaud [25] showed that this also has a mobile methyl group, and will support the growth of rats on a methionine-free diet containing homocystine. The thetin chlorides are more active in this respect than betaine, and also, as was shown by Dubnoff and Borsook [26], in the formation of methionine from homocysteine in liver and kidney preparations by the enzyme transmethylase. Neither thetin has yet been found in animals.

These results suggested a search for the presence of sulphonium compounds in other plants. Lupin seeds, unroasted coffee beans, and the seeds of Indian mustard (*Brassica juncea*), on heating with sodium hydroxide and aspirating the vapours through mercuric chloride, gave no dimethyl sulphide, although the seeds of the last-named plant are stated to contain it. The detection of dimethyl sulphone in the *Equisetaceae* suggested the presence of a sulphonium compound. With hot sodium

hydroxide, in an air-stream, the intact plants of *Equisetum telmateia* (*E. maximum*) and *E. fluviatile*, and the spore-bearing cones of *E. palustre*, yielded small quantities of dimethyl sulphide, characterized as the mercurichloride. Mercaptans were absent. It is almost certain that the sulphide did not arise from the sulphone by reduction, as on heating this with sodium hydroxide, glucose, and filter paper (to simulate as far as possible the experimental conditions) no dimethyl sulphide was formed. The reduction of the very stable sulphone under such conditions was hardly to be expected. The common bracken (*Pteridium aquilinum*), especially the young shoots, readily evolved dimethyl sulphide, characterized by the melting-point and mixed melting-point of the mercurichloride, the sulphilimine

$$((CH_3)_2S{\rightarrow}N.SO_2.C_6H_4.CH_3),$$

and benzyldimethylsulphonium picrate. The fern *Athyrium filix-femina* also yields very small quantities of the same sulphide with hot alkali. During a study of the sulphur compounds of asparagus, Mrs M. I. Whitaker (Miss Simpson) found that an evaporated acetone extract gives traces of dimethyl sulphide, which was again detected as the mercurichloride. It seems very probable that methyl sulphonium compounds occur fairly frequently in plants.

Jansen [27] has recently isolated from asparagus 2:2'-dithiolisobutyric acid,

$$(HS.CH_2)_2.CH.COOH,$$
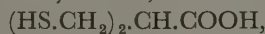
in its disulphide form. 1-Keto-2-thiolpropionic acid (β-thiolpyruvic acid), $HS.CH_2.CO.COOH$, may conceivably be a precursor of this acid.

The keto-acid, arising from cysteine by oxidative deamination, might condense with acetic acid, and by loss of water and carbon dioxide the resulting product could yield the unsaturated acid. Addition of hydrogen sulphide (arising by enzymatic action on cysteine) could then take place, giving the dithiolisobutyric acid:

$$HS.CH_2.CH(NH_2)COOH{\rightarrow}HS.CH_2.CO.COOH$$
$$\xrightarrow{H.CH_2COOH} HS.CH_2.C(OH)(COOH).CH_2.CO_2H$$
$$\xrightarrow{-HOH} HS.CH_2.C(COOH){:}CH.COOH \xrightarrow{-CO_2}$$
$$HS.CH_2.C(CO_2H){:}CH_2\xrightarrow{H.SH}(HS.CH_2)_2CH.CO_2H$$
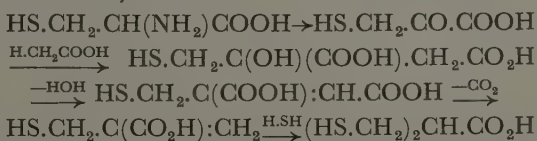
Such addition reactions are known to occur with hydrogen sulphide or mercaptans and αβ-unsaturated carbonyl compounds. The intermediate stages in this scheme are analogous to the postulated mechanism of formation of citric acid in mould-cultures (where interaction of acetic acid and malic or oxaloacetic acids has been suggested)

and to its conversion respectively to aconitic and itaconic acids, which have been detected in sugar beet and in cultures of various *Aspergillus* spp, including *A. terreus*.

TOXICITY OF A SULPHOXIMINE IN AGENIZED FLOUR

Some two or three years ago attention was devoted to the toxic action (resulting in hysteria and convulsions) produced in dogs and certain other animals by flour which had been treated with traces of nitrogen trichloride vapour in order to improve its baking properties. The original observation was made by Sir Edward Mellanby [28], and further work was carried out by him, by Moran [29], and by Bentley [30] and their colleagues, who all arrived at similar results. The toxic factor arises from the action of nitrogen trichloride ('agene') on the protein gluten contained in the wheaten flour. Other proteins, e.g. zein, casein, egg-albumen, haemoglobin, and rice-protein also become toxic under this treatment, but keratin and arachin do not. The proteins which become toxic have a relatively high methionine content, while the others contain little or none of this amino-acid. Moreover, when casein and zein are partially oxidized by hydrogen peroxide, whereby the methionine residues are affected, the resulting product does not become toxic on treatment with nitrogen trichloride. On the other hand, free methionine, and the products of hydrolysis of zein and casein, yield no toxic product with agene, the products in the case of methionine being the sulphoxide or the sulphone. Zein, gluten, and egg-albumen were therefore treated with nitrogen trichloride vapour, and the resulting product was hydrolysed either by the enzyme pancreatin or by chemical means. A long series of operations, including dialysis, extraction with phenol, hydrolysis, extraction of by-products with butanol, precipitation with acetone, electro-dialysis, ion-exchange fractionation, partition chromatography, and crystallization from alcohol yielded a product $C_5H_{12}O_3N_2S$. With Raney nickel, α-amino-*n*-butyric acid and nickel sulphide were formed. Determination of —NH_2 nitrogen showed the presence of only one amino-group. The formula

$$CH_3\overset{\overset{\textstyle NH}{\uparrow}}{\underset{\underset{\textstyle O}{\downarrow}}{S}}.CH_2.CH_2.CH(NH_2).COOH$$
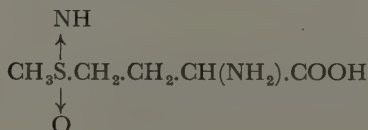
was therefore suggested for the new compound.

This type of structure, which presents analogy with those of the sulphoxides $\overset{R}{\underset{R}{>}}S{\rightarrow}O$ and the sulphones $\overset{R}{\underset{R}{>}}S\overset{\nearrow O}{\searrow O}$, was not previously known.

The compound was named methionine sulphoximine, and was synthesized from methionine sulphoxide and sodium azide and sulphuric acid in chloroform solution:

$$CH_3S(O).CH_2.CH_2.CH(NH_2).COOH + HN_3 =$$

$$CH_3\overset{\overset{\textstyle NH}{\uparrow}}{\underset{\underset{\textstyle O}{\downarrow}}{S}}.CH_2.CH_2.CH(NH_2).COOH.$$
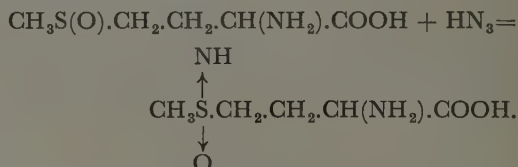
It was identical in melting-point, crystal form, chemical reactions, behaviour on a paper chromatogram, and physiological action, with the compound from agenized protein. The simplest representative of the sulphoximines, $(CH_3)_2S\overset{\nearrow O}{\searrow NH}$, has been prepared in a similar manner from dimethyl sulphoxide. Several analogues of this sulphoximine have been synthesized [31], e.g. the di-*n*-amyl, diphenyl, and methyl-*p*-tolyl compounds, and also the sulphoximine derived from S-methyl-cysteine, $CH_3.\overset{\overset{\textstyle O}{\uparrow}}{\underset{\underset{\textstyle NH}{\downarrow}}{S}}.CH_2.CH(NH_2).COOH.$
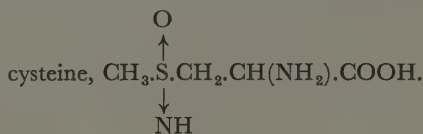
NATURAL α-TERTHIENYL AND POLYACETYLENES

The author and others [32] found isomeric dithienyls in the purified distillate from the interaction of acetylene and boiling sulphur. Later, Sease and Zechmeister [33] isolated α-terthienyl from the flowers of the Indian marigold, *Tagetes erecta* (*Compositae*). Many members of this natural order contain polyacetylene derivatives; thus Sörensen and Stene [34] isolated the diolefinic diacetylene Me.CH:CH.C∶C.C∶C.CH:CH.CO.OMe from *Matricaria inodora*, a plant closely allied to the common camomile. The corresponding dihydro-derivative

Me.CH₂.CH₂.C∶C.C∶C.CH:CH.CO.OMe

occurs in *Lachnophyllum gossypinum* [35]. Carlina oxide (benzyl-2-furylacetylene) occurs in the oil obtained from the roots of *Cirsium acaule*.

It may be more than a coincidence that the only instance so far recorded of the occurrence of a true thiophen derivative in plants should be found in a family of which so many members contain poly-acetylenes. The α-terthienyl may arise by inter-action of hydrogen sulphide (possibly derived from cystine) with a straight chain compound containing an acetylenic-olefinic system, and perhaps also some methylene groups, as in the last compound cited above. Other reactions such as oxidation, decar-boxylation, or dehydrogenation might be involved. It could be argued that a long-chain paraffin or fatty acid might serve equally well as the starting-point. Ring closure would, however, undoubtedly be facilitated by the presence of olefinic and ace-tylenic linkages.

A natural product with a modified thiophen nucleus is β-biotin, which contains a urea residue condensed with a tetrahydrothiophen ring carry-ing a $—(CH_2)_4.COOH$ side-chain. Many natural unsaturated fatty acids, including the acetylenic derivatives erythrogenic acid,

$$CH_2{:}CH.C{\vdots}C.(CH_2)_4.C{\vdots}C.(CH_2)_7.COOH \text{ or}$$

$$CH_2{:}CH.(CH_2)_4.C{\vdots}C.C{\vdots}C.(CH_2)_7.COOH, \text{ and}$$

tariric acid, $Me.(CH_2)_{10}.C{\vdots}C.(CH_2)_4.COOH,$

contain the grouping $—(CH_2)_4.C{\vdots}C—$, and it is possible that both the heterocyclic ring and the side-chain of biotin may arise from an acid of this type.

Biocytin (ε-N-biotyl-lysine), a peptide of biotin in which the heterocyclic ring carries the side-chain

$$—(CH_2)_4.CO.NH.(CH_2)_4.CH(NH_2).CO_2H,$$

has been isolated from yeast. Like biotin, it promotes the growth of several micro-organisms.

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George Wilson (1631-1711)

F. W. GIBBS

Although a brilliant new discovery from time to time brings about a rapid advance, the progress of science depends to a great extent upon the accumulation of knowledge by workers who may be virtually forgotten by later generations. To many, there seems to have been a lull in the progress of chemistry in Britain between 'The Sceptical Chymist' and Black, but in fact it was a time of considerable activity. George Wilson was one of those who during this period contributed to the advancement of chemistry by their writing, lecturing, and experiments.

George Wilson, citizen and haberdasher of London, was one of 'those dexterous and wonderful conscientious Artificers, the Chemists . . .', as the admiring apothecary-physician Quincy called them. He began to practise his art—for it had not yet become a true science—about three hundred years ago. Though he lived in an age of alchemy and natural magic, of secret processes and secret remedies, Wilson quickly established for himself a reputation for honest dealing, for openness, and for welcoming to his laboratory all who were genuinely interested in chemistry and medicine.

For about twenty years his furnaces were situated in the parish of St Mary Aldermary, at the sign of 'Hermes Trismegistus,' in Watling Street. For rather more than the last twenty years of his life he prepared medicines, experimented, and taught practical chemistry to physicians and medical students at the sign of 'Hermes' Head,' in Well Yard, West Smithfield. This was where the east wing of St Bartholomew's Hospital now stands, with the parish church of St Bartholomew the Less within the hospital boundary. Here Wilson was buried, though no trace of the position of his grave can now be found, owing to the reconstruction of the church in the eighteenth century.

In that shadowy period of the history of chemistry in Britain between the two luminaries Boyle and Black, Wilson stands out as a notable figure.

George Wilson

He is important since his textbook, 'A Compleat Course of Chymistry,' first printed in 1691 and sold at his house, formed the basis of many public courses of lectures from then until the middle of the eighteenth century, the last edition being published in 1746. For this reason alone it might have been expected that some notice of Wilson's life and work would be found in the standard histories of chemistry, but strangely enough they neglect him.

The third edition of his book (1709) contained an engraved portrait, giving the information that Wilson was then flourishing at the age of seventy-eight. Though this does no more than indicate 1631 as the probable year of his birth, it is the only biographical information about him in the reference books. Wilson himself gave a few more details. In addition, some isolated facts have been obtained through the kindness of the Governors of St Bartholomew's Hospital (whose archives include the early registers of the church) and of the Worshipful Company of Haberdashers. His will may be consulted at Somerset House, and there are several lists of assessments of various kinds in the Guildhall Library and the Corporation Records Office that refer to him. By these means, and from his printed bills and newspaper advertisements, it is possible to give an account in broad outline of his life and work. The records enable us to trace him back from 1711 to 1668, but there the trail
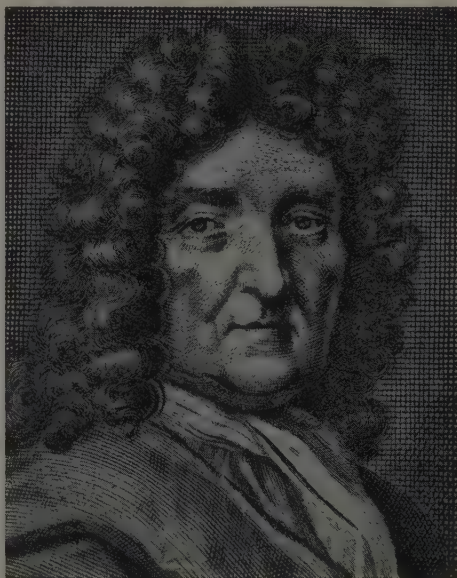
breaks. Doubtless the reason is to be found in the upheavals of the period, resulting from the Plague (1665) and the Great Fire of London (1666).

Nothing can be said with certainty of Wilson's origin or early training. Everything points to a humble background; he certainly lived in a very modest fashion throughout his life. In his book he referred to his lack of 'the great blessings of academical education,' adding that he had no more philosophy than he had 'fetched out of the fire' in his laboratory. When Boyle's 'Sceptical Chymist' was published in 1661, Wilson, then aged thirty, was trying out the claims of an alchemist friend, a practice he did not entirely drop until towards the end of his days. He was then also making medicines for private sale and for several of London's leading apothecaries and physicians.

During 1665, the year of the Plague, Wilson was kept very busy making such preparations as 'diaphoretic arsenic,' 'soap of tartar,' and 'compound spirit of vipers,' with which many physicians vainly but courageously attempted to do battle with the dread disease. He also made the 'arsenical magnet' (by heating together arsenic, sulphur, and antimony), which was used in plasters or in amulets carried on the person. It was a time of great strain for those chemists and apothecary-physicians who stayed in London, as there was a continuous call on their services from which there was no escape. Many of them fell victims to the disease and perished, among them George Starkey (another 'philosopher through the fire'), famous for his skill in chemical preparations, especially those containing quinine and opium. Wilson saw Starkey a little before his death and obtained from him the composition of his celebrated pills, the original of the 'compound soap pills' that first found their way into the London 'Pharmacopoeia' in 1746. The 'soap' in both Starkey's pill and that of Matthews (to whom Starkey sold the secret of an earlier variant of this preparation) was made from salt of tartar and oil of turpentine, and was added as a corrector or aperient to extract of opium.

Wilson survived the Plague, but the Great Fire of 1666 forced him to leave his work for about a year. As soon as possible he returned to his furnaces, and in October 1667 he was engaged in alchemical experiments on mercury. The church records of St Mary Aldermary, though interrupted for a time, were again kept normally in 1668, and the tithe assessments for that year show Wilson to have been in the house in Watling Street where he remained until the end of the reign of James II. At about this time he became a member of the Haberdashers Company, an entry in the 'freedoms register' stating that he was freed by order of the Court of Aldermen on 27th November, 1668. That he joined the Haberdashers is further proved by his will, in which he not only stated the fact but showed that he frequented the Loriners' Hall; the Haberdashers used this hall because their own was destroyed in the Fire.

Nothing more is known of him for the next nine years, but in 1677 he was again experimenting with mercury and various amalgams. This work ended unsuccessfully, for after heating six hermetically sealed 'eggs' for fourteen months they exploded without warning, and much of his material was lost. He also concocted a preparation to relieve his rheumatism, from which he had suffered a considerable time; this he afterwards sold as the 'anti-rheumatick tincture,' which became a very popular remedy and was the mainstay of his family for a number of years. He occasionally lodged physicians and others who wished to learn about chemical preparations.

These somewhat isolated facts are confirmed and put in a clearer light by a printed bill which Wilson issued in 1686, a copy of which is preserved in the British Museum. It bears the title '*Gaza Chymica:* or, a magazin, or storehouse of choice chymical medicines.' It was addressed to all 'Doctors of Physick, Apothecaries, Chirurgions, and others, Studious of Physick, or curious in Chymical Operations.' Besides showing the relationship of chemists to apothecaries, surgeons, and physicians at that time, it gives a list of several of the favourite remedies of the age, some of which could be obtained only from Wilson, '*Philo-Chymicus.*' He wrote: 'I here offer to your service the conveniency and use of my Laboratory, if any of you shall at any time desire it, there to have any particular Process of your own experimented, paying for the Coals and Glasses, and a Reasonable Recompense for the Use of my Furnaces. And at all times a Free and Welcom access to see any of those Medicines you shall have of me, prepared from the beginning to the compleating of the same. . . .'

Largely because of the popularity of Starkey's pills and the anti-rheumatic tincture, Wilson's preparations were becoming widely known. Among his patrons was William Paston, Earl of Yarmouth, F.R.S., Treasurer of the (Royal) Household from 1686 to 1689. It was doubtless through him that James II was regularly supplied from Wilson's laboratory with sweet honey-water (or rose and orange-flower water, as the Household accounts

show it). This preparation 'smooths the skin, and gives one of the most agreeable scents that can be smelt. Forty or fifty drops put into a pint of clean water, are enough to wash the hands or face with; and the same proportion to punch, or any cordial-water, gives a most pleasant flavour.' It was made from honey, coriander seeds, cloves, nutmegs, benzoin and styrax, vanillas and lemon-rind, all mixed with French brandy and distilled. Rose-water, orange-flower-water, musk, and ambergris were added to the distillate.

The patronage of an unpopular monarch and some of his supporters was not an unmixed blessing, for in December 1688, when the emotions of the London populace were inflamed on hearing that William of Orange had landed and was approaching the city, Wilson's laboratory was ransacked by a mob: his alchemical trials were mistaken for a sinister plan to burn Whitehall. The glasses in his athanor had been heated continuously for nearly seven months when, on 11th December . . . 'I was treated as the *Spanish* Ambassador was, For the Mob taking me for a Conjurer, or something worse, broke my Glasses and Athanor, saying, I was preparing the Devil's Fireworks, purposely to burn the City and *White-Hall*; and thus ended this Operation.'

After this episode Wilson moved to Well Yard, in St Bartholomew's, where he found a house through the interest of the Earl of Yarmouth, to whom he afterwards admitted his many obligations, saying that all he enjoyed at home was to be attributed to the Earl's care and goodness. No evidence has been found to show that Wilson gave public courses of lectures before 1690, but it seems likely that he did so, as his book of 1691 was intended partly to help those studying chemical processes under him.

These courses were most successful, and in 1694 he advertised them in John Houghton's weekly paper, 'Collection for Improvement of Husbandry and Trade,' where there were several insertions in April, May, and June. As this is one of the earliest of such advertisements, it may not be out of place to reproduce it.

'A course of Chymistry will be carried on by *George Wilson*, at the *Herme's* Head in *Well-Yard*, behind St. *Bartholomew's* Hospital in *Smithfield*, in which will be performed above *One Hundred* several Operations. They who desire to know such a Process, with all its necessary *Attendants*, may, for Three *Guineas* each, be accommodated, if they will before the Second of *July* next pay to Mr. *Marmaduke Brown*, Stationer, at the Sign of the Cross-Keys on *Ludgate-Hill*, near *Fleet-Bridge*, *Two Guineas*, and Subscribe for the payment of the *third Guinea* when the Course shall be half run through, that he may provide Necessaries for the carrying it on.'

Though Wilson was perhaps the best known practitioner in pharmaceutical chemistry at that time in London, he was not without competitors, both as to courses of chemistry and in anti-rheumatic preparations, for in 1696 two further persons advertised in Houghton's paper. The first, William Johnson, was experienced in both chemistry and physics, which he had studied while in Boyle's employment. 'Courses of *Chimistry*, with Experiments on the *Air-Pump*, Mr. *Boyle*'s Experiment of *Colours*, or any of his Experiments of what sort soever, may be seen at any time at the sign of *Van Helmont's Head* in *Fetter-Lane*. . . .' The other stated that 'At the *Blue-Balls* and *Chymical Furnaces* in *Alia-street* in *Goodman's Fields*, near the *Black-Horse*, may be had *Balsamum Anodinum*, or a Balsam that safely and surely gives Ease to all Manner of Pains. . . . The like of this never appear'd in publick before.'

Wilson's life in Well Yard was peaceful, and he was able to devote himself to his chemical pursuits without interruption. His book reached a second edition in 1699, and a third in 1709, to which he added an account of those alchemical studies that had led him to renounce the doctrine of transmutation. It is possible that, like some itinerant lecturers of the eighteenth century, Wilson had the title-page of the book changed from year to year, as copies bearing the dates 1698 and 1700 are also known.

Of his private life little has come to light. His wife Mary assisted him in his work and was trained to prepare the anti-rheumatic tincture, which was sold not only at the 'Hermes' Head,' but by his son Edward at the 'Old Hen and Chickens,' near the New Exchange in the Strand. Edward died young, leaving two sons, Yelverton George and Robert. Wilson advertised his last course for 16th April, 1711 ('Daily Courant,' 5th April), but there is some doubt as to whether he actually gave it. He died a few months later, probably on 15th August, and was buried in the parish church of St Bartholomew the Less on 17th August. In his will he noted that he had given his late son Edward an ample portion, and found he could leave his grandsons only five shillings each, which they were to receive on reaching the age of twenty-one. His books, manuscripts, and recipes were left to his wife, who continued to support herself and her widowed

daughter-in-law with the help of the tincture until the end of 1715, when she was ordered to leave the house in Well Yard. After this, the family returned to the obscurity from which it had temporarily emerged.

It is no easy matter to attempt to assess Wilson's position or influence in chemistry, for much of the necessary background for such an appraisal is still lacking. However, some facts show that his work was not without effect on the subsequent developments in this science. Wilson had helped to create a demand for chemical courses, and since these were required mainly by medical students, the demand lasted well after his day. They were at first taken over complete by Edward Bright, a chemist with a laboratory in Whitefriars, near Fleet Street. He gave a course, on the lines popularized by Wilson, in 1711 and some subsequent years. In one of his last bills, Wilson was able to say that he had introduced many gentlemen to 'the excellent and useful Science of Chymistry, of which number there are many Eminent Physicians now living in England, Scotland, Ireland, France, Italy, Germany, Swedeland, etc.' It is also significant that a fourth edition of his book was brought out in 1721 and a fifth in 1736.

Those British and continental European authors who mention his work speak of him as an expert and faithful chemist, and this is the view of him that is presented in the writings of the apothecary-physician John Quincy, who referred to him as 'Honest' George Wilson. The numerous editions of Quincy's 'Compleat English Dispensatory' included many of Wilson's preparations—sweet honey-water, now dignified with the name *aqua mellis aromatica*, the *Pillulae Starkei, laudanum balsamicum* (an opium preparation communicated by one who had been familiar with Wilson), a 'pectoral, sudorific, Liquid Laudanum,' and many others from that 'experienced and faithful Chemist.'

For his time Wilson was exceptionally clear in his descriptions and, despite the fact that some of his processes remind one of magic—the amulet against the plague, and the 'elixir of human skulls' for curing madness, for example—he showed far less credulity than the majority of his contemporaries. 'I have all along studied Brevity,' he wrote, 'and therefore have rejected those things which are frivolous, or of little Use: And my Answer to them who find Fault with the Stile is, Perspicuity was more my Endeavour than Ornament; thinking it sufficient in Matters of this Nature, if I can be understood without any difficulty.'

In this respect Wilson's book is almost unique in seventeenth-century chemical literature, owing perhaps to the fact that he did not attempt to mix philosophy or theory with his accounts of practical work. Those who look for theoretical advances will find none in his book, though clarity such as his made it possible for Peter Shaw, writing only twelve years after Wilson's death, to say that a reformation in chemistry had at last begun—chemical authors had dropped their studied darkness and obscurity, and a little plain sense had been introduced instead. Moreover, the shops of the apothecaries had been eased of the unwieldy lumber under the load of which they had groaned for so long.

In the 1730's two lecturers on chemistry were coming into prominence—Shaw himself, who gave a course in London in 1731, and William Lewis, fresh from Cambridge, where he graduated M.B. in that year. Shaw adhered to the view that a proper study of chemistry would not only prove of value to medicine, but that British arts and manufactures, on which the country relied then as now, could be greatly improved if men trained in physics and chemistry were set to the task of studying outstanding problems and of devising methods of producing goods which hitherto had been imported. Lewis adopted Wilson's book and Shaw's ideas as the basis of his courses in a laboratory off Fetter Lane, given 'with a view to the improvement of pharmacy, trades, and the art itself.' During the preparation of several such courses, Lewis had collected much information not known to Wilson, and he considered that a new edition of the book, with the additional matter, should be printed. This was published in 1746, and by its means Wilson's natural talent for clear, unsophisticated writing continued to exert an influence on the chemists of the mid-eighteenth century. And with Lewis's tribute (he was then a Fellow of the Royal Society), written nearly a century after Wilson had begun to be interested in what was then an almost secret art, this account will end. 'The favourable reception which the public had given to the *Complete Course of Chemistry* . . . and the character which Mr. *Wilson* has long bore amongst the learned in the medical art, both with regard to his fidelity as a writer, and ability as an operator, have long ago engaged me to have frequently recourse to his work: and I must with pleasure own, that I have all along found him, upon repeated trials, to deserve the reputation he has acquired.'

Humming-birds

J. BERLIOZ

There are certain groups of living creatures so specialized that it is difficult to relate them in any way to others of their kind. Among the birds, the *Trochilidae* or humming-birds form such a group, numbering altogether some three hundred species. Their minute size, their splendid plumage, and their rapid humming flight are known to everyone. Though limited to the Americas, they are hardier and more widely distributed than is generally realized.

For a long time, the humming-birds or *Trochilidae* were believed to be closely related to the nectar-feeding *Passeres*, and in old classifications these birds made up the *Tenuirostres*. More recently they have been classified with the swifts. The first of these classifications was based on similarities of the beak and in the nature of the food, the second on structural analogies in the limbs and tail. However, the first is merely a case of limited convergence between creatures in most respects utterly unlike, and the second bears witness to at most a very distant relationship. Moreover, in some respects humming-birds resemble quite different types; in the structure of the head and beak, for example, they are not unlike the woodpeckers. Briefly, in internal and external structure, the *Trochilidae* form a homogeneous group quite different from other birds.

The humming-bird's beak and tongue are those of a typical nectar-feeding bird. The beak is thin and elongated and more or less cylindrical, the tongue bifurcated and capable of being considerably protracted. The sternum is very large, relatively to the total size of the bird, and carries the strong pectoral muscles which confer on the humming-bird its exceptional powers of flight—it is among the fastest and most agile of all birds. The wings move on axes formed by the short bones of the fore-limbs, the structure of which produces the characteristic insect-like flight, consisting in a continuous series of rapid beats in a spiral pattern. The feet are short, and terminate in four strong claws. They are useless for movement on the ground, and serve only for gripping a perch; the humming-bird's sole means of locomotion is by flying.

The bird's movements are disconcertingly swift and sudden. At one moment motionless on its perch, at the next it flashes away, swift as an arrow, to feed. It will hover before a flower for a second or two, then dart off at an angle to visit another, then streak away towards the sky; it is unique in being able to fly backwards as easily as forwards. This incomparable acrobat is as truly at home in the air as its namesake, the humming-bird hawk-moth. Insect and bird are so alike that it is difficult to distinguish between them in flight.

The humming-bird's flight is accompanied by a characteristic note, whose pitch increases with the frequency of the wing-beats. This frequency ranges from 12 to 15 beats per second in the largest species (the size of swifts) up to 50 or more in the smallest (the size of bumble-bees). The speed of flight is such that it is often easier to detect a humming-bird by sound than by sight. In countries where many species are found, it is said to be possible to identify a species by the characteristic note in relation to size: other details may be lost owing to the rapidity of the flight, and the changing of the colour according to the changing light.

The hues of humming-bird's plumage equal in splendour that of the finest butterflies. This is not due to the presence of pigments, however. Simple pigments are certainly present in the feathers, but the latter owe their colouring principally to a microscopically fine lamellar structure which diffracts the incident light, forming beautifully dappled patterns. The appearance of these 'optical' feathers depends more on the variation of the daylight than on their pigmentation; dark and sombre on certain days, on others they present brilliant colours.

Earlier authors have aptly compared these colours with those of precious stones. The male ruby-topaz humming-bird (*Chrysolampis mosquitus*) has a ruby-red head tending towards violet, while the throat is of a striking orange or yellow topaz-like hue. The throat of *Myrtis Fanny* is of a unique aquamarine blue. The dark plumage of *Heliangelus micraster* is relieved by a patch that shines in certain lights with the fire of glowing embers. Green,

FIGURE 1 – Heliangelus micraster *Gould* ♂ (*Andes of southern Ecuador*).

FIGURE 2 – Damophila Juliae (*Bourcier*) ♂ (*western Colombia and Ecuador*).

(All illustrations natural size.)

FIGURE 3 – Helianthea Eos *Gould* ♂ (*Venezuela, western Andes*).

FIGURE 4 – Heliomaster squamosus (*Temminck*) ♂ (*eastern Brazil*).   (*J. Berlioz pinx.*)

FIGURE 5 – Popelairia popelairei (*Du Bus*) ♂ (*Amazonian region of Colombia and Ecuador*).

(*Natural size.*)

FIGURE 6 – Spathura peruana *Gould* ♂ (*eastern Andes of Ecuador and Peru*).

(*J. Berlioz pinx.*)

however, is the dominant colour, in all shades from bronze-green (which seems to be the basic colour of the plumage) to the deepest emerald, and this is relieved by patches of black or pure white with the happiest effect.

It is often believed that this brilliant colouring is shown only by the males, the females of so many species being of relatively dull hue. This is so in general, but there are many exceptions to the rule. In many perching-birds the female is the more variable sex in appearance, and this fact, in combination with the iridescence of the plumage, produces in some species a near identity of the two sexes. Some humming-birds, and those not the least brilliant, show no difference at all in plumage between the two sexes—such, for example, are the rainbow (*Panterpe insignis*) and the garnet (*Eulampis jugularis*). This andromor-

phism of the females is virtually restricted to the colour of the plumage, however. The development of ornamental feathered structures, important taxonomically at specific and generic levels—collars in *Lophornis* and *Popelairia*, modified tail-feathers in *Acestrura*, *Myrtis*, and allied genera, etc.—is largely restricted to the male sex.

The ornamental feathers worn by some male humming-birds can to some extent be explained by the sort of teleological theory which attributes to them a role in mating behaviour. It is, however, more difficult for such a theory to explain the substantial differences in the form of the beak which exist in these birds. The range of plants visited for food is extremely wide, but there is no evidence of any adaptation of beak-form to any particular type of flower. Whether the beak is curved, as in *Eutoxeres*, or straight and pointed, as in *Helianthea*,

the length and mobility of the tongue enables the birds to visit all manner of flowers and obtain from them both nectar and tiny insects; the latter are themselves attracted by the nectar and make up the most important part of the birds' food. Humming-birds are, indeed, more insectivores than nectar-feeders, and some species live exclusively on animal food. These are highly skilled at catching their insect prey on the wing.

Although their wide range of food-plants enables the humming-birds to exist where flowers are scarce, most species show a tendency to congregate where conditions are most favourable. They are naturally commonest wherever climatic factors, such as those in the tropical rain-belts, or abundant flower-bearing crops, ensure a plentiful supply of food.

Humming-birds are found throughout the Americas, from the north of Canada to Tierra del Fuego in the south. They can be seen in all latitudes, at the proper season, for, in spite of their minute size, these birds migrate over long distances. All that is essential for their presence is a supply of flowers and insects. Even deserts with cacti can support a humming-bird population. Some mountain species can withstand low temperatures, and *Chalcostigma Stanleyi* nests in the craters of volcanoes in Ecuador at an altitude of over 14000 ft., not far below the snow-line. Some 430 forms of humming-bird are at present recognized, making up nearly 300 species.

I have observed these interesting birds in many parts of the New World—Mexico, Brazil, and Ecuador. I have never seen them in greater numbers than in the orange plantations of Itatiaya, Brazil, though only a few species were there represented, and these mostly common ones. The sweet-smelling flowers of the orange-trees attracted them like flies, and they were to be seen at all hours humming greedily about this abundant source of food. Three species predominated, namely *Thalurania glaucopis*, *Leucochloris albicollis*, and *Agyrtrina brevirostris*, of which the first two are notable for their pugnacity. These tiny birds will not put up with the presence of a competitor, and at the first sign of approach will hurl themselves on the enemy to chase him away with their beaks. In these surroundings, the abundance of food goes some way towards suppressing the native pugnacity of the humming-birds, and most combats result from the chance meeting of two individuals in search of a new source of nectar.

Humming-birds visit flowers most frequently in the morning and evening. In the middle of the day they are occasionally absent for some time, and it is then that I have seen emerge from among the leaves those other tiny birds, the flower-peckers (*Caereba*), coming to suck the nectar from the same flowers, but these take themselves off at the first sign of the humming-birds' return.

Not all humming-bird species exhibit this natural pugnacity to an equal degree, nor does it seem to be related to size. Some groups, such as the *Phaethornis*, have always seemed to me less aggressive, and some of them even show signs of social behaviour, except at times of pre-nuptial combat. The beautiful *Heliothrix*, silky green above and pure white below, often shows a remarkable timidity in spite of its dagger-like beak, flying without resistance before an adversary much smaller than itself.

This aggressiveness of the humming-birds leaves little place in the Americas for other flower-loving birds. How do they themselves react to a shortage of flowers, apart from by migration? Darwin noted that on Juan Fernandez, an island poor in phanerogamic life, the humming-birds (*Sephaniodes fernandensis*) lived mostly on small arthropods. In desert regions, travellers have seen humming-birds feeding off rotting cactus fruits, which they will not normally touch. I have myself observed humming-birds in Mexico during the dry season visit large spiders' webs, and it is fascinating to watch their noisy flight as they pick tiny insects from the threads with their long sticky tongues. They also help themselves to drops of dew accumulated on the web, and will take the spider itself if it is not too large. It is said that their liking for spiders' webs leads them occasionally into danger, and that they themselves may fall victims to the spider.

Most humming-birds show a fondness for running water, in which they like to moisten their plumage. They are to be seen frequenting mountain torrents and waterfalls, as well as fountains in the parks of towns (for they adapt themselves readily to contact with man), not only for the sake of the insects which abound in such localities, but also for the evident pleasure they show in brushing their wings against the jets, passing sometimes right through them with their rapid zig-zag flight.

This desire for moisture must not be overlooked by those who wish to keep humming-birds in captivity. Up to the beginning of this century such attempts had failed in Europe, owing to the necessity of perfectly fresh food, ignorance of a correct diet, and the difficulty of rapid transport. Nowadays success has been achieved, and the Zoological Gardens at Copenhagen boast a specimen that has lived for more than eight years in captivity.

The wave-forms of atmospherics

M. W. CHIPLONKAR

As one of the most spectacular of natural phenomena, lightning has always aroused great curiosity. Atmospherics, equally familiar to the modern man, form a subject of comparatively recent attention, having come into existence as such only through the invention of radio communication. The present article gives a *résumé* of the investigations carried out by numerous workers during the past fifty years on these two apparently distinct groups of phenomena, and shows how a study of the one leads to a study of the other, to a better understanding of both, and ultimately to the realization that they are closely related.

Atmospherics or 'statics' are the transient and erratic electromagnetic disturbances which hinder the smooth working of radio communication. In a radio receiver they generally produce loud noises familiar to the listener as clicks, crackles, crashes, rumbles, and so on; these cease as soon as the aerial is disconnected. It has long been known that they are more numerous, and stronger, in cities and highly industrialized areas than in the open country. This difference was soon found to be due to the proximity of electrical equipment in the former localities, and so, an obvious distinction being available, atmospherics were divided into two classes—natural and man-made. An atmospheric known as the high-frequency cosmic static or 'the Jansky noise' [9] has been the subject of many recent investigations and is now proved beyond doubt to originate in certain parts of the Milky Way, and in the Sun and its spots. The exact mechanism of its generation is still unknown. It is proposed in this article to deal with the natural atmospherics and further to restrict attention to those of terrestrial origin.

THE ORIGIN OF NATURAL ATMOSPHERICS

Since atmospherics are electromagnetic in nature, they are propagated in space in exactly the same manner as ordinary radio waves. From their source they spread out in all directions, and often reach very distant places. Hence, in spite of the numerous efforts made to eliminate their disturbing effects, no real success has so far been achieved. In the early days of radio communication, atmospherics were studied to discover their frequency characteristics. Their spectrum was found to be very wide, extending from a few kilocycles per second to five or six megacycles per second. The majority (exceeding 60 per cent.), however, have frequencies lying between 5 kc/s and 10 kc/s. Their energy level decreases as the frequency in-

creases, generally from a very large value at low radio frequencies to an almost negligibly small value at ultra-high frequencies. The number of atmospherics received at any place shows diurnal and seasonal variations, and also directional distributions peculiar to each place. Climatic and geographical conditions thus clearly determine both their number and their manner of variation, a fact surmised by Marconi [13] as early as 1906.

A definite advance in our understanding of the nature and origin of these electromagnetic disturbances was made twenty years later, when Watson-Watt [25] showed for the first time that they originate in regions of strong convective activity in the atmosphere such as exist in duststorms, thunderstorms, and thunderclouds. Schonland and his co-workers [19] finally traced the origin of these natural atmospherics to actual lightning discharges in the earth's atmosphere.

THE LIGHTNING DISCHARGE

Our exact understanding of lightning may be said to have begun with the series of pioneer experiments by Simpson [22] and Wilson [27], started nearly half a century ago. They were primarily undertaken with a view to elucidating the fundamental process of separation of charges in a thundercloud. Using a simple capillary electrometer, Wilson measured the sudden changes in the electric field near the ground caused by neighbouring lightning discharges (figure 3a). He concluded that a thundercloud is a huge electric . dipole with a positive charge at the top and a negative charge at the base, and that during a lightning flash the potential difference is destroyed in a small fraction of a second. Later workers [15, 19, 28] repeated these experiments in other countries, and extended the observations even to very distant lightning flashes, using rapid and very

sensitive electronic circuits and cathode-ray oscillographs.

Next, the actual mechanism of a lightning discharge was revealed, notably by the brilliant series of researches of Schonland and his co-workers [14, 15, 18, 19, 21] in South Africa. They investigated simultaneously both aspects of a lightning discharge, namely the electrical and the luminous, from two stations distant from one another. The variation of the electric field due to a lightning discharge was observed by cathode-ray oscillographs, and the variation in the luminosity of the same lightning channel was revealed in the photographs taken simultaneously with a Boys camera [3] (figure 1). This comparative study of lightning, with a similar study of the spark discharge in the laboratory, disclosed altogether new facts and showed that the mechanism of a lightning discharge is very complicated. Briefly, there are three stages. The preliminary stage is completed when a sufficiently large amount of charge of one sign has accumulated in a particular portion of a thundercloud. As regards the fundamental question of how the separation of charges takes place in the cloud, we may say here that possibly both the 'breaking drop process' and the 'influence
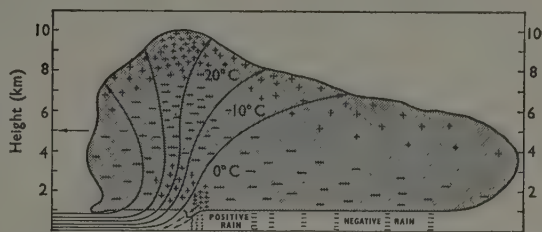
FIGURE 2 – *A generalized diagram showing air currents and distribution of electricity in a typical heat thunderstorm (Simpson and Scrase).*

process,' suggested respectively by Simpson and by Wilson, are at work simultaneously; their ultimate effect is to accumulate positive charges in the top portions of the cloud lying above the — 10° C isothermal surface, while negative charges spread out in the lower portions. Occasionally an additional positive charge is found concentrated in a small region in the lower front portion, where a strong convection current enters the cloud [23] (figure 2). The intense field in the vicinity of these charged regions then ruptures the insulation locally, and what is known as a brush discharge begins. Naturally, some charge flows instantaneously in a direction that is favourable, and further ionizes that region. At the end of this path the field increases, the process repeats itself, and the charge moves forward. This short, step-like process goes on until a long zig-zag path of distributed charges is formed, connecting the two oppositely charged portions of the same or neighbouring clouds, or a cloud portion and the ground below. Such a flow of charge is called the 'stepped leader,' and is supposed to start, as a rule, from a region of high density of negative charge and to move towards the region of positive charge either induced by it or produced otherwise (figure 4). In this process it often happens that more channels than one are formed, and branching of the leader takes place away from the negative electrode. Near the end of this zig-zag path, if the field of the oppositely charged region is sufficiently strong, a similar streamer starts in the opposite direction and meets the first one half-way. This completes the second stage. Once a conducting path is established between two points, a large amount of positive charge flows back instantaneously, i.e. in the direction opposite to that of the stepped leader, and completes the return stroke, which is heavy and intensely dazzling. This normally finishes the third stage. In many cases, however, this is followed by a number of unidirectional or to-and-fro
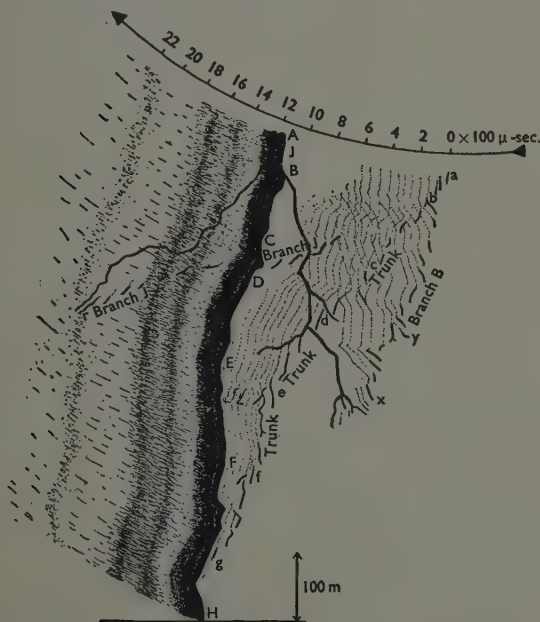
FIGURE 1 – *A line drawing made from the enlargement of a typical photograph, obtained with the Boys camera, of a cloud-to-ground discharge. The leader trunk follows the course abcdefg corresponding to ABCDEFH on the rapid return stroke. The lens movement is along a circular arc from right to left (Schonland, Malan, and Collens).*

movements of comparatively small amounts of charge along the same channel. Occasionally, the stepped leader alone is produced, and the corresponding return stroke never occurs. The whole process of discharge takes place on the average in about a hundredth of a second, and each lightning flash thus destroys a large amount of charge in a very small space of time. The process of building up charges then starts again.

ATMOSPHERICS CAUSED BY LIGHTNING

It was pointed out by Simpson that, as regards the emission of electromagnetic radiation, a lightning-channel may be likened to a huge aerial possessing appropriately distributed capacitance, inductance, and resistance, and so every flash of lightning gives rise to a characteristic electromagnetic pulse or wave. It must also be noted that all these distributed properties of the discharge-channel are not fixed, but vary from moment to moment; therefore a simple pulse or a regular wave is only rarely emitted.

The electrical effects accompanying a lightning-discharge can simply be considered in the following manner. The vertical electric field at a distance r from the vertical discharge-channel of length h and dissipating charge Q is given by the equation:

$$E = \frac{M}{r^3} + \frac{1}{cr^2}\frac{dM}{dt} + \frac{1}{c^2r}\frac{d^2M}{dt^2},$$

where $M = 2Qh$, the cloud moment, and $c =$ the velocity of light. Here the values of the cloud moment are the retarded values obtaining at a time $(t - r/c)$. E is the resultant vertical field at the point of observation, produced by the electrostatic effect of the stationary charge (say Q), the induction effect of the varying charge in the discharge-channel (proportional to dQ/dt), and the radiation effect of the rate of change of varying charge in the channel (proportional to d^2Q/dt^2), all occurring at a distance r. A comparison of the three terms on the right-hand side of this equation shows that the electrostatic effects will be predominant for only very small values of r, up to about 8–10 km. The second term, accounting for the effect of induction, also becomes insignificant beyond about 15–20 km. Beyond a certain distance (about 100–200 km), only the effects due to radiation are important.

THE WAVE-FORMS OF ATMOSPHERICS

Numerous attempts were early made to record the true forms of atmospherics, but they met with no real success. For instance, a large number of records were obtained with the rather slow equipment at first available, and classified variously according to their shapes and durations—by Appleton, Watson-Watt, and Herd [1] as 'periodic,' 'quasi-periodic,' and 'aperiodic'; by Norinder [16] as 'clicks' or singlets, and 'grinders' or multiplets; and by others [2] similarly. With later improvements in the electronic circuits and cathode-ray oscillographs, far greater time-resolution and more faithful delineation of the field-changes could be achieved. Thus in 1934, from the wave-forms of atmospherics recorded during daytime, Watson-Watt, Herd, and Lutkin [26] first established the regular variation of wavelength with distance of the lightning channel from the receiver. In many cases, they found a high-frequency component followed by a low-frequency one (figure 6). Similar work has been in progress in Australia since 1935, and the first evidence that atmospherics observed by day are reflected from the ionosphere was obtained by Laby, Nicholls, Nickson, and Webster [10] in 1937 (figure 5). They suggested that the variation in the high-frequency part of the atmospheric, which shows during the day as a damped wave-train of gradually increasing wavelength, is itself a consequence of multiple reflection of a simple pulse of very short duration between the ionosphere and the ground. From his later observations in England, Lutkin [12] suggested that in most cases the daytime wave-form arises from oscillations and multiple discharges in the lightning channel itself. Again, Laby and co-workers [11] found in 1940 that their former explanation could not readily be reconciled with the majority of the wave-forms recorded during the daytime, unless they assumed that the first five half-periods arose directly from the parent lightning-discharge. Later, however, Schonland, Elder, Hodges, Phillips, and van Wyk [20] showed that the wave-forms of all the atmospherics observed in South Africa at night arise from the propagation-mechanism suggested originally by Laby and his co-workers in 1937 (figure 7). In India, Chiplonkar and Hattiangadi [6] developed their own technique (figure 9) and recorded several hundred wave-forms of atmospherics at night. A marked majority of them showed the phenomenon of multiple reflection, with an average number of 10–15 (even, occasionally, as many as 40) reflections (figure 8). A classification of the wave-forms of atmospherics recorded at Cambridge, England, in 1947–51 has been published by Caton and Pierce [5].

Most of these wave-forms may be divided into
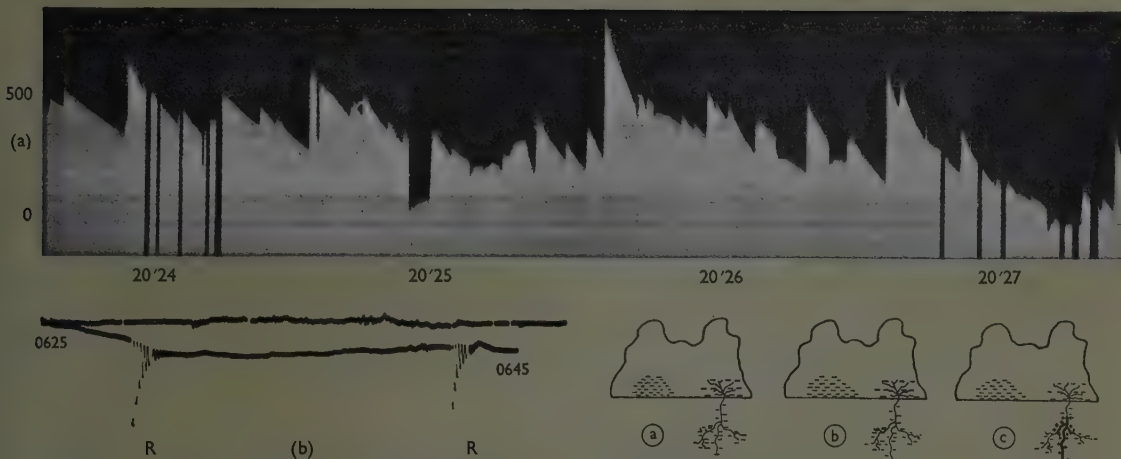
FIGURE 3 – *Field changes due to lightning recorded with capillary electrometer connected to raised metal sphere. Field in volts/metre on vertical axis and time on horizontal axis. The vertical dark lines mark the beginning of the thunder from which the distances of the respective lightning channels are deduced. (a) Record on 17th June, 1917, from storm at distance of 15–20 km (Wilson). (b) Record obtained 23rd September, 1937, with an undamped Dolezalek electrometer connected to a raised copper sphere (Chiplonkar). Note the 'field recovery' curves.*

FIGURE 4 – *Different stages of a lightning flash, diagrammatic. A major portion of the negative charge tapped is lowered at* (a), *positive streamers begin from the other end at* (b) *and* (c), *a mere conducting path exists at* (d); *the single channel without branches used by the afterstroke is seen at* (e) *and* (f) *(Schonland).*
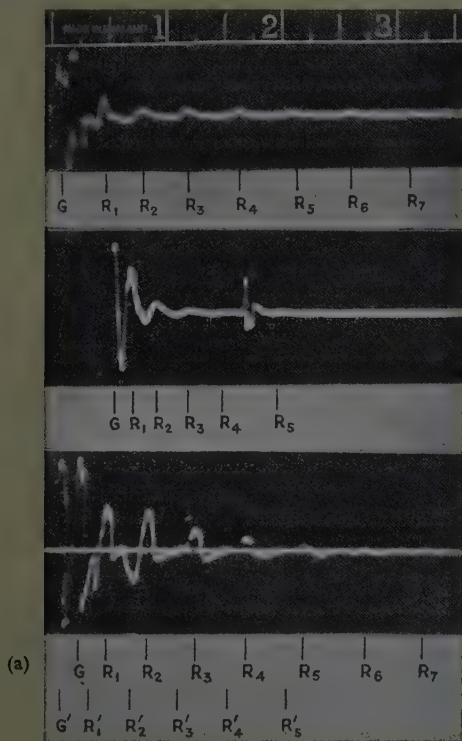
FIGURE 5 – *Atmospheric oscillograms from lightning distant 250–510 km. G is the ground wave, R_1, R_2, .., R_7 are the reflected waves. In* (a) *two sets of reflections G .. R_7 and G' .. R_5' appear. Time-scale at top: 1 unit = 0·001 sec (Laby and co-workers).*
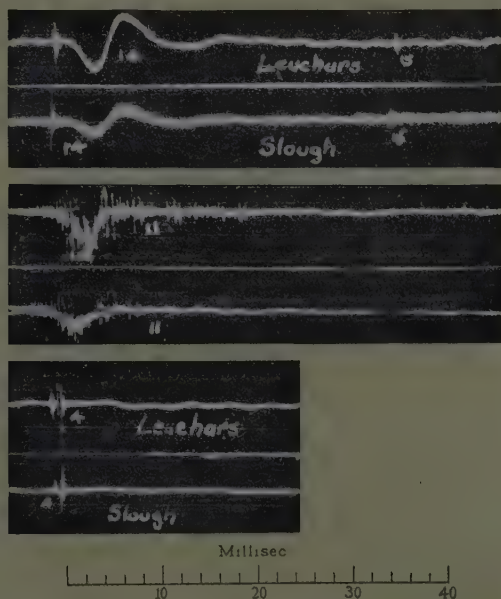
FIGURE 6 – *Typical wave-forms recorded simultaneously at Slough and Leuchars (p. 195), showing similarity. Note large time-scale and unresolved high-frequency components (R. A. Watson-Watt, Herd, and Lutkin).*
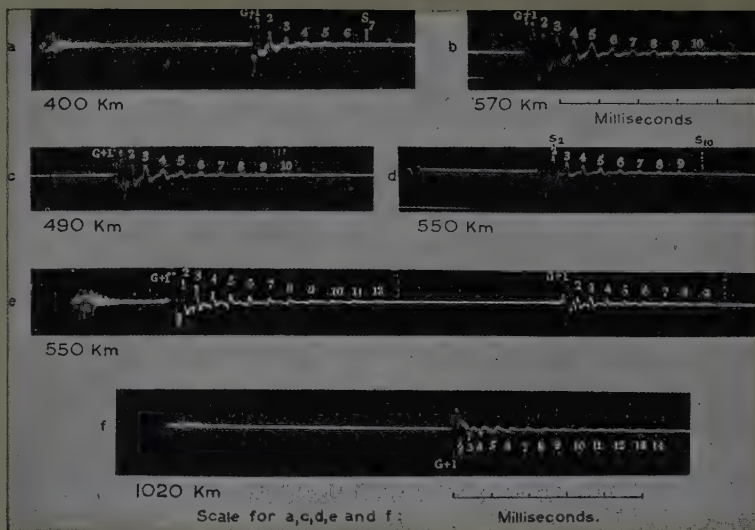
FIGURE 7 – *Typical wave-forms of atmospherics observed at night. Note the elegant recording of the precursors too (Schonland and others).*

TYPE II
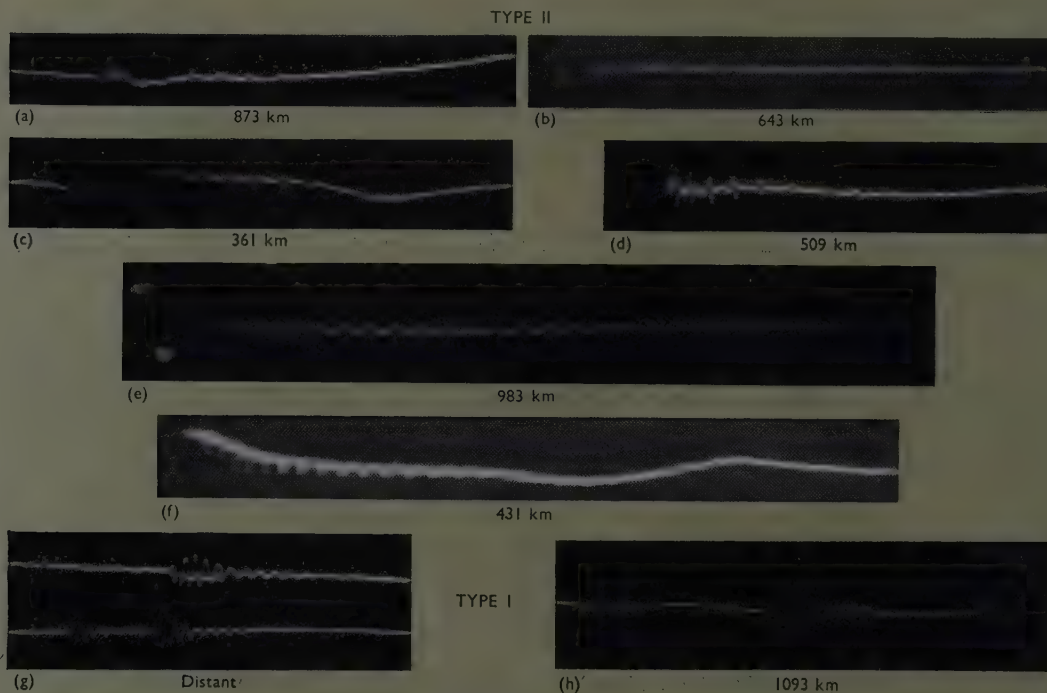
FIGURE 8 – *Typical wave-forms of atmospherics observed at night at Poona (India). They are so grouped as to bring out the distinction between the 'irregular' and the so-called 'smooth' or sinusoidal wave-forms. Note the large number of sky pulses in those of type II (Chiplonkar and Hattiangadi).*
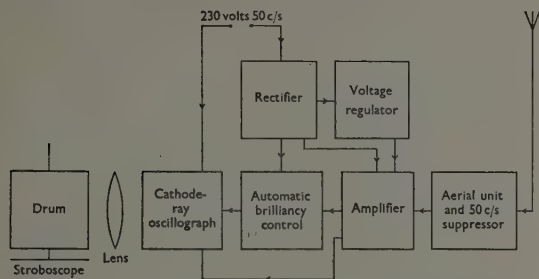
FIGURE 9 – *A schematic representation of the apparatus set up at Poona (India) for recording the wave-forms of atmospherics (Chiplonkar and Hattiangadi).*

two main groups: (i) those arising from discharges between cloud and cloud, and (ii) those arising from discharges between cloud and ground. The wave-forms in the first group were found to contain a large percentage of high frequencies superposed on only a small number of reflections from the ground and the ionosphere. The second group could be shown to consist of the following three distinct portions: (*a*) high-frequency oscillations of no definite character; (*b*) the main pulse; and (*c*) a number of well separated pulses almost similar in form to the main pulse but decreasing in amplitude.

THE PROPAGATION MECHANISM

According to Laby (1937), the wave-form of an atmospheric consisting generally of the above three distinct portions arises from three equally distinct causes (figures 10(*a*) and (*b*)). The random, very high frequency precursors visible in many records are produced by, and correspond to, the several high-frequency pulses emitted during the dart-like advances of the stepped leader, while the main pulse coming after them is caused by the first heavy return stroke of the lightning-discharge. Both these portions of the record indicate the arrival of the electromagnetic waves following the direct path between the source and the receiver. The succeeding pulsatory movements or oscillations of charge in the discharge-channel are also often seen to produce subsidiary pulses immediately following on the main pulse. In the series of more or less similar but discrete pulses recorded after the main pulse, each individual similar pulse indicates the arrival of a different portion of the wave-front of the main pulse after a number of reflections, alternately at the ground and at the ionosphere.

This interpretation of the recorded wave-forms of atmospherics in terms of the ray theory offered a novel method of obtaining such information

about the ionosphere as its height above the ground and its reflection coefficient for these long waves. The height of the ionosphere has in fact been estimated in this way by Laby and co-workers as 78–82·5 km, by Schonland and others as 88·5–91·5 km, and by Chiplonkar and Hattiangadi as 91·5 km (average of 388 observations). Values for the reflection coefficient range from 0·60 to 0·95.

From the complete wave-forms thus recorded, elementary forms of the main pulses have been carefully selected and classified into different groups, depending upon their shapes and durations. For instance, Schonland and co-workers found the pulse-duration to range from 50 to 400 microseconds, and the forms were divided into three groups; in India they ranged from 150 to 600 microseconds and were grouped into four classes. Pulses with more complicated shapes and longer durations are naturally supposed to be produced from simpler forms, either during their generation or by the propagation mechanism suggested above.

In India, precursors were clearly traced in about 10 per cent. of the cases, while Lutkin found them in about 15 per cent. and 17 per cent. of the records at Slough (England) and Leuchars (Scotland) respectively. A careful study of the precursors in relation to the corresponding main pulse does not reveal any relationship between the dart-like advances and the return stroke.

THE WAVEGUIDE-MODE THEORY

The simple ray theory of Laby outlined above explains satisfactorily most of the experimental facts regarding the wave-forms of atmospherics. There is also another way of looking at the phenomenon, namely to consider the ground and the
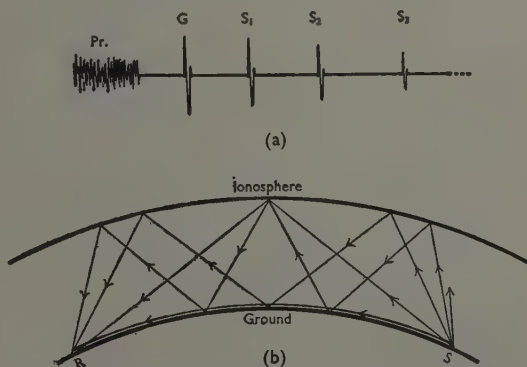
FIGURE 10 – (a) *An idealized wave-form of an atmospheric.* (b) *The propagation of an electromagnetic pulse on the ray theory.*

(a)

(b)

(c)
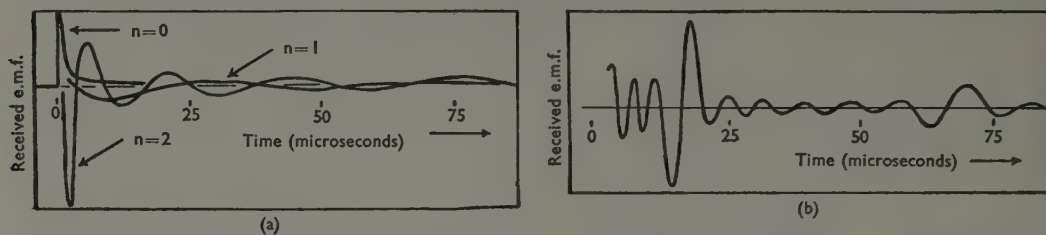
FIGURE 11 – (a) *Received e.m.f. in the first three modes at 1000 km from 'lightning flash.' The waveguide is assumed to have perfectly conducting walls separated by a distance of 50 km.* (b) *Sum of received e.m.f.s in the first seven modes (n = 0 – 6 inclusive).* (c) *Impulses received according to the ray theory (Budden).*

(Figures 1–4 and 6 and 7 by courtesy of the Royal Society; figure 5 from 'Nature' by courtesy of the publishers; figure 11 from 'The Philosophical Magazine' by courtesy of the publishers.)

ionosphere as the two parallel conductors of a waveguide which conveys the radiated electromagnetic energy through the intervening space in accordance with its characteristic modes of propagation. The subject of long-wave propagation over the globe has been treated in general from this point of view by Watson [24], Eckersley [7], Rydbeck [17], and others. More recently, Hales [8] and Budden [4] have applied the same method to explain the observed wave-forms of atmospherics. The exact calculation of the received

signal by this waveguide-mode method gives more or less the same results as those obtained by the much simpler ray method. At the same time, it is interesting to see how, in the waveguide-mode method, a mere consideration of the relevant number of modes contributing to the received electromotive force successfully explains the transition from the wave-form consisting of a succession of sharp and irregular pulses to the characteristically smooth and oscillatory form, as the distance of the source of atmospheric is increased gradually (figure 11).

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The earliest figures of microscopic objects

CHARLES SINGER

Although the compound microscope was in use as early as 1609, its immense scientific possibilities were not generally appreciated until much later. Nevertheless, a number of interesting observations were made in the early seventeenth century, and a few records of them still exist in the form of engravings of the original drawings. Those of Francesco Stelluti showing the anatomy of bees are outstanding, although still comparatively unknown.

The early history of the compound microscope is still not clear. There is, however, no doubt that it was Galileo, then a professor at Padua, who launched it on the scientific world in 1609. His first microscope was merely an inversion of the telescope that he had just invented. In the opening passage of his *Sidereus Nuntius* (1610), a very short work—hardly more than a pamphlet—which records more important discoveries in fewer pages than any other book ever written, he says:

'Two months ago a rumour reached me that an optical instrument had been made by a Hollander, by the aid of which far-distant objects were distinctly seen as though near. This was confirmed a few days later by a letter from Paris. Therefore I applied myself to seeking out the theory and discovering the means for the invention of a like instrument. This end I reached by considering the theory of refraction. I prepared a leaden tube, to the ends of which I fitted two glass lenses, both plane on one side but one being spherically convex, the other concave, on the other.'

Next year a Scot, John Wodderborn, issued at Padua a defence of certain astronomical views expressed in the *Sidereus Nuntius*. In the course of it, Wodderborn gives us our first glimpse through the microscope: 'A few days back,' he writes, 'I heard Galileo narrate, to that noble philosopher Signor Cremonino, how he perfectly distinguished with his telescope (*perspicillum*) the organs of motion and of sense in the smallest animal and notably in a certain insect in which each eye is covered by a thick membrane, which septum, however, is perforated with holes like the vizor of a warrior, thus affording a passage to the images of visible things.' Galileo was referring to the compound eyes of insects, the functioning of which has ever since been a scientific problem.

Wodderborn's book is dedicated to the witty—and correspondingly unsuccessful—diplomat Sir Henry Wotton (1568–1639), then at Venice. Wotton was a friend of Francis Bacon, Milton, Izaak Walton, and many scientific and literary men, and doubtless brought news of the microscope to England. He had always shown an interest in optics and vision, so that Wodderborn's dedication to him is quite intelligible. Cesare Cremonino (1550–1631), the recipient of Galileo's information on the microscope, was a professorial colleague of Galileo at Padua, and an obstinate Aristotelian. Cremonino refused to look through Galileo's telescope—and doubtless was equally unwilling to look through his microscope. He had another link with Galileo, for later both fell under ecclesiastical censure.

For twenty years after its invention the compound microscope aroused surprisingly little interest among scientific men, who were far more excited by the telescope and its revelations. Thus records of observations with the microscope at this period are extremely rare, but a French visitor to Galileo at Florence in 1614 says that he was still employing as a microscope his old inverted telescope, though Kepler in 1610 had shown the possibility of a better form. Casual wonder was, however, aroused among the non-scientific public by enlarged images of fleas, flies, itch-mites, and cheese-mites, so that magnifiers, simple or compound, became known as flea-glasses or fly-glasses. One reference to them is relevant here. Nicholas Fabri de Peiresc (1580–1637), himself a graduate of Padua, was one of those whose copious correspondence served, before the advent of scientific journals, the function of keeping learned men informed of activities in the world of research. In 1622, Peiresc wrote from Paris to the secretary of Francesco Barberini (Cardinal 1623, Vatican librarian 1627): 'There is a *periscope* or *occhiale*, a new invention different from that of Galileo [doubtless a Keplerian microscope], which shows a flea as large as a cricket and almost

of the same shape. It has two larger limbs and the other legs smaller. The head and almost all the rest of the body are armed with crusts or scales, as with locusts or small shrimps. The minute animals generated in cheese, called by us *mitti* [mites], so tiny that they are as dust-grains, when seen with this instrument, become as large as flies without wings. They are clearly seen as having very long legs, a pointed head, and every part of the body quite distinct.' In 1623, Francesco Barberini's uncle, Maffeo Barberini, became, as Urban VIII, the Pope (1623–44) under whom Galileo was condemned in 1633.

In 1624 Galileo wrote to one who must be held to be the first who occupied himself with microscopy, Federigo Cesi, thus:

'Herewith an *occhialino* for examining minute things at near distance. I hope that from it you will have as much use and enjoyment as I. Its despatch has been delayed because I had not reduced it to perfection. The object should be attached to the mobile stage at the base and so moved as to bring the whole into view, since only a small part can be seen at a time in the *occhiale*. That there may be just the right distance between lens and object, the glass must be advanced or withdrawn, the little tube being made movable on its base and adjustable as desired. With infinite wonder I have examined very many minute creatures, among which the most horrible are fleas, and the most beautiful ants and moths. With delight too I have seen how flies and other little animals can walk on mirrors and even upside down. You have now vast opportunity to observe thousands and thousands of details and I beg you to send me news of the most curious of them.'

Cesi (1585–1630) was a wealthy nobleman interested in science from his youth. Before he was twenty he had gathered round himself a small group of scientific men, Galileo and Stelluti among them. This band formed the nucleus of the first *Accademia dei Lincei*, 'Companions of the Lynx,' as they called themselves. By the time that Cesi received Galileo's microscope, the Linceans had increased in numbers and included many of the most important men of science of their day. The word microscope was coined by one of them in 1624, and was generally used in their correspondence. The Academy had, for various reasons, incurred the suspicion of the Inquisition. As an act of prudence, the members invited Cardinal Francesco Barberini to become their president. He declined, but the Lincei continued to court his patronage, with certain consequences for the his-

tory of microscopy, as we shall presently see. Cesi applied himself to microscopic observations, the results of which he proposed to incorporate in a great *Theatrum Naturae*, which he did not live to complete.

One of the earliest of the Lincei was Johann Faber of Bamberg (1574–1629). Writing in 1628, he gives us news of Cesi's microscopical work on plants. 'Cesi,' he wrote, 'commissioned an artist to make drafts of numerous plants, hitherto regarded by botanists as seedless, but clearly revealed by the microscope to be teeming with seeds. Such is the wonderful and minutely fine dust adherent to the backs of the leaves of the polypodium fern and appearing as big as peppercorns. When in due course his books and studies of plants see the light, we shall possess numberless other novel observations.' The objects in question were the sporangia containing the spores of the fern emerging from the indusium. They were perhaps the first objects beyond the range of unaided vision that were seen with the help of the microscope, and these are the first recorded microscopic observations on plants. Cesi's figures of the sporangia of a fern are lost, but Faber goes on: 'With this microscope Stelluti has marvellously set forth for us the external anatomy of the bee. All this, however, I had rather that you should see with your own eyes than learn from my poor pen.' In fact very few indeed, even to this day, have seen the figures which now lie before the reader of ENDEAVOUR.

Francesco Stelluti (1577–1646) was among the first group of Linceans, and remained the most active member of the young society. The *Apiarium* which he produced with Cesi in 1625 contains the earliest figures still extant drawn with the aid of the microscope. The only perfect copy of this work is probably that in Rome, at the library known by the name of its founder, Giovanni Maria Lancisi (1654–1720), a far-seeing papal physician who rescued from loss by neglect many important monuments of early science and learning. The only other known copy of the plate is imperfect. It is, or was, possessed by the Scottish Bee-Keepers' Association in Edinburgh, to which we owe the photograph from which our separate figures of bees have been reproduced. The only copy of the text known to us outside the Lancisian Library is owned by Mr R. Lier of Geneva, who has most kindly lent it to us for study.

The text itself must be a record for its date in the size of the printed opening, $39\frac{1}{2}$ in by 25 in, and is in small print. It is dedicated by Cesi

FIGURE 1 – *Plate from what is probably the only perfect copy of Federigo Cesi's* Apiarium *(Rome, 1625), now in the Lancisian Library in Rome. It is reduced to ⅗ of the original size.*

FIGURE 2 – *Arms of the Barberini family. The three bees had suggested the plate of the* Apiarium. *The figure is from an Italian translation of the 'Satires' of the Latin poet Persius* (A.D. 34–62), *issued at Rome in* 1630 *and dedicated to Cardinal Francesco Barberini. Note the cross and cardinal's hat above the shield and between the putti which support it. In the notes in the book the translator, Stelluti, gives in reduced form the figure of the bees from the* Apiarium. *He describes in some detail the various parts of the insect. This is the earliest account of insect anatomy.*
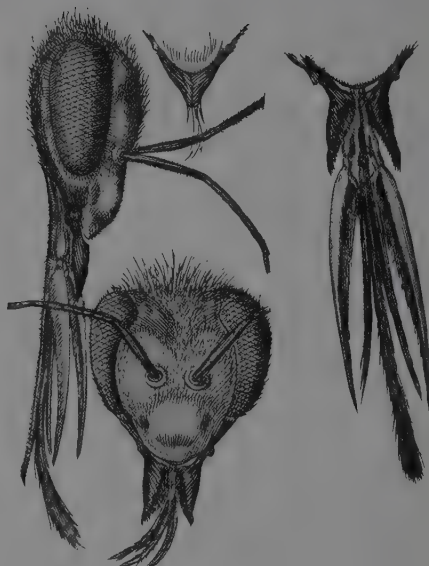
FIGURE 3 – *Head and mouth-parts of bee, from Cesi's* Apiarium (*Rome,* 1625), *of the size there presented.*

FIGURE 4 (*left*) – *One of the bees from the* Apiarium, *of the size there presented.*

to Urban VIII. The arms of the Barberini family, a shield of three bees, suggested these animals as the subject. The text is a mass of somewhat misapplied learning, but it contains a reference to the microscope and telescope, the uses of which are contrasted. It includes a description of every kind of bee and wasp known to the Lincei, including some American species, the first attempt to display a group of insects thus.

The accompanying plate also is very large, measuring more than $14\frac{1}{2}$ in by $10\frac{1}{2}$ in. It is dated clearly 'Rome 1625' in the bottom left-hand corner. At the right is a statement that it was both drawn and engraved by Mathias Greuter (1564–1638), a well-known artist from Strasbourg who was active for many years in Rome. He seems to have worked on a first draft by Stelluti. It is mentioned in the text that the observations were confirmed by the Flemish Lincean Justus van Rycke (Riquius,

1587–1627). The plate shows three bees, magnified about twenty diameters, hovering between two branches of flowering bay. At the top of that to the left a bambino holds the papal crown, while his companion to the right bears the key of St Peter. Below are figures of the head, mouth-parts, compound eye, sting, and posterior legs of a bee, all somewhat further enlarged. The scroll above bears an inscription which can be translated:

'To His Holiness Pope Urban VIII, on the presentation to him by the Academy of the Lynx, as a token of everlasting devotion, of an accurate delineation of the bee.' The scroll below bears Latin verses which may be thus rendered:

'O great Parent of the universe, to whom Nature willingly submits herself, and before whose lordly feet she kneels, behold the bee from the scutcheon of the Barberini family, than which nothing in all nature is more remarkable. This bee, an achievement worthy of the Companions of the Lynx who have examined it with closer gaze, has been set forth and expounded in pictures (with the spirit of Cesi urging on the sacred toil and the art of Pallas aiding the eager men), while under the polished glass rise the greatest marvels and the eye learns to magnify its faith. Who would have known that there are five tongues in the body of the bee, that the neck is like a lion's mane, that the eyes are hairy, that there are two sheaths to each lip, were it not for the divine discoveries of the new art? Thus it is fitting that, while the world looks up to thee [Urban VIII] in wonder, thy bee should show itself to be a yet greater wonder'.

This is not quite the end of the Lincean Barberini bees. In 1630 Stelluti published at Rome, with the Lincean printer Mascardi, an Italian translation of the 'Satires' of Persius. It is dedicated to Francesco Barberini. It bears the Barberini family arms surmounted by a cardinal's hat. In the work, a reference to bees is adorned with reduced figures of those which appeared in the *Apiarium*. The following account is attached to the figure: 'Prince Cesi has discoursed of these bees with the greatest erudition, ingenuity, and originality, condensing volumes into a single page. I [Stelluti] also have used a microscope to examine bees and all their parts, the form of which I have here rendered, for they are worthy of the attention of all. I have also figured separately all those members discovered by me with the aid of the microscope, to my no less joy than marvel, since they are unknown to Aristotle and every other philosopher and naturalist. For greater clearness, moreover, I enumerate, part by part, each of the members as verified by Signor Fabio Colonna, a Companion of the Lynx, who, on my suggestion, made the same investigation on this wonderful little animal. That which Signor Colonna examined and interpreted was then drawn by Signor Francesco Fontana. Then I, on my part, caused to be engraved here in Rome in compliment to our noble lord, Urban VIII, three large bees, drawn in such detailed form as was revealed by the glasses of the microscope, and I had them figured from three aspects, front, back, and side, as may be seen on the adjoining page.' The mention of the Neapolitan, Fontana (1580–1656), introduces a complication, for there are thus three claimants to have drawn the bees—Stelluti, Greuter, and Fontana. The last, in after years, did in fact make a few microscopic observations of his own, and claimed to have invented the instrument!

Among the details which Stelluti records in this account of 1530 are: 'The eyes are large and oval and covered with a chequered membrane, like the eyes of other insects. . . . Instead of hairs the head has feathers like those of birds [referring to branched hairs]. . . . Immediately under the beak is a tongue, round, many-jointed, and hollow beneath. The bee extends it to suck up honey. The tongue is equipped with four accessory tonguelets [the mouth-parts of the creature]. . . . When the bee is not using the tongue it retracts it under the beak, folded, with its tonguelets towards the neck'.

In view of this beginning in the use of the microscope, it might reasonably be expected that the instrument would immediately have become more widely used for scientific purposes, and that a gradual accumulation of microscopic observations would have resulted. This, however, does not accord with the facts of history. For thirty-five years following this publication, records of observations made with the microscope are extremely rare. Why there should have been this pause has not yet been fully explained. The chromatic and spherical aberration of the compound instrument must certainly have discouraged and confused observers. It would also seem that the arts of making, mounting, and using simple lenses of very short focal length had not yet been mastered. At any rate, the next important microscopical observations were those contained in the magnificent *Micrographia* (1665) of Robert Hooke. He worked with a compound instrument, though his immediate successors turned to the use of simple lenses. Of the microscopical researches of Hooke we hope to give some account in a future issue of ENDEAVOUR.

Some aspects of the biology of armoured scale insects

F. BARANYOVITS

Although much progress has been made in the control of insect pests, there are many against which we are still virtually powerless. Outstanding examples are the armoured scale insects, the bane of citrus growers, which not only show a general resistance to modern insecticides but have a tough protective coat and restricted times of feeding which further limit their vulnerability. The search for weaknesses in their defences has revealed many factors of great biological interest in these seemingly simple organisms, but the problem of control remains.

Control of armoured scale insects remains one of the more important problems of the economic entomologist, for these serious pests of fruit trees have proved to be very resistant even to potent modern insecticides. It is generally believed that the insect owes this resistance mainly to the protective scale which covers its body, but the fact that it survives on the leaves of citrus plants that have been rendered toxic to red spider mites by systemic insecticides suggests that some other factors may be involved as well. Since not enough is known about the anatomy and physiology of scale insects to account for this phenomenon, which is not shown by the closely allied aphids and leafhoppers, it was decided to study the special characteristics of the armoured scale insects in the hope of finding reasons for their resistance, and possibly their vulnerable points. More information was also needed to resolve difficulties that had been met with in rearing the insects for insecticide-sorting work. This article records the results of investigations that have so far been made, with a few introductory notes on scale insects in general.

GENERAL FEATURES AND MOULTING

Scale insects belong to the *Coccidae*, a family of the order *Hemiptera* or true bugs; they are related to the *Aphididae* or aphids. A few scale insects are beneficial to man, notably the lac insects (*Laccifer* spp) of India and the Far East, the cochineal insects (*Dactylopius* spp) of Mexico, and the Chinese wax insect (*Ericerus pe-la*), but the family owes its fame—ill fame, rather—to the success of its members as plant pests.

The family is well distributed throughout the old and the new worlds, and it has an extraordinarily wide range of hosts. Apple and aspidistra, banana and begonia, palm and pine—plants of nearly every order—are subject to attack by one or more species. Fruit trees in the tropics and sub-tropics, however, and ornamental plants grown in greenhouses, provide the chief hosts of economic importance. In particular, scale insects are a menace to the citrus industry in most countries where this crop is cultivated. Generally speaking, the problem of control arose when orchards first became infested by non-endemic scale insects, for rapid increase of the newly introduced pests was favoured by the absence of their normal parasites and predators as well as by the new climate. A good instance is the San José scale insect, *Quadraspidiotus perniciosus*, which is of minor importance in its native home in China, but became a very serious pest when it was introduced into the United States and southern Europe.

The armoured scale insects or *Diaspinae* are highly specialized plant-parasites, and owe their success to several remarkable adaptations. Most obvious of these is the hard cap—the armoured scale. Beneath this scale, the insect seems to be glued for ever to its host plant (figures 2 and 3), yet it has brief phases of mobility. Whether the species lays its eggs under the protective scale or produces its young direct, the first nymph or crawler is able to move about for a distance of a few feet. Once it has found a spot at which to feed, it inserts its feeding tube, or rostralis, into the tissues of its host, and there remains anchored to sit and suck for the rest of its life, if a female, or until it reaches maturity, if a male.

In the course of development the female moults twice and the male four times; the female insect attains a diameter of about 1 mm at maturity. The crawler of the first stage (figure 11) resembles a young aphid and has eyes, antennae, and six legs; but these organs are lost with the first moult,

FIGURE 1 – *California red scale insect on orange leaf (right) and, showing destruction of chlorophyll, on lemon leaf (left).* ($\times$ 0·75)

FIGURE 2 – *California red scale insect. Heavy infestation on orange twig.* ($\times$ 6)

FIGURE 3 – *California red scale insect: (below) mature female with scale removed; (above) male pupae.* ($\times$ 10)
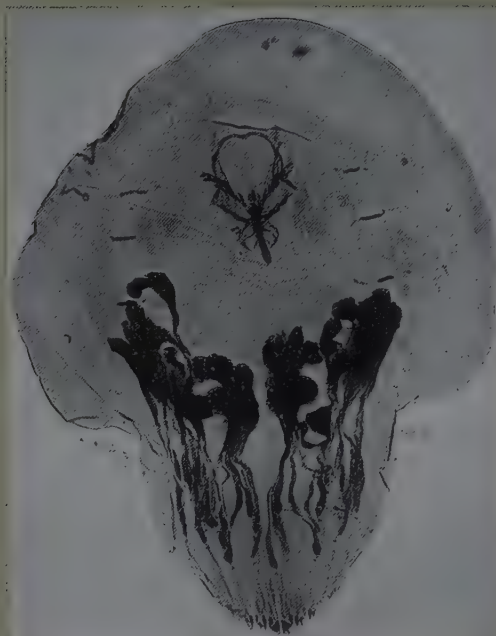
FIGURE 4 – *California red scale insect. Cleared preparation of a fully developed female, showing silk glands and posterior lobes.* ($\times$ 100)
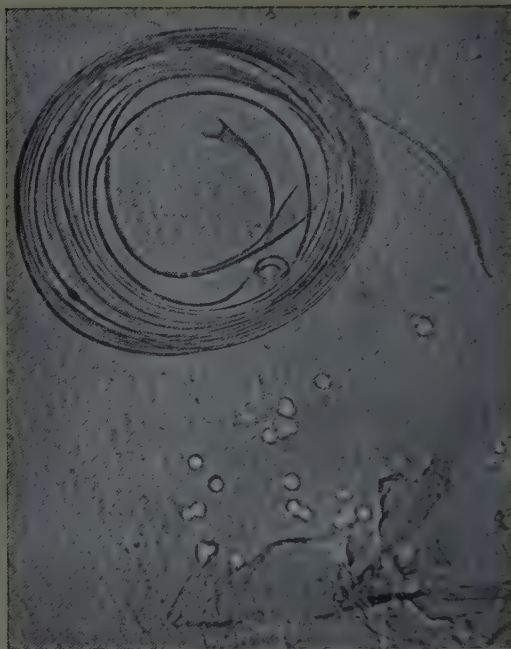
FIGURE 5 – *California red scale. Cleared preparation, showing separate stylets in one coil of developing rostralis (above) before passing through the buccal frame (below).* ($\times$ 430)

and even the separation into head, thorax, and abdomen—typical of insects—can scarcely be observed. The female never regains these appendages. The male, however, emerges from the final instar with antennae and wings, by means of which it can detect and fly to the much larger females. Its mouth-parts and its digestive system are not functional.

The sedentary nature of the pest might seem to inhibit its natural spread, yet it is because of this very fact that the scale insects are readily carried from place to place on infested plants and, aided also by wind and other mechanical agencies, achieve their local and world-wide distribution.

Another feature that guarantees their success is the rapidity with which they multiply. Reproduction is normally sexual, but in some species it is also parthenogenetic; fertility is high. Both eggs and young are shielded from their natural enemies and sheltered from the elements by the mother insect. There may be four generations in a season. Hence, losses are soon made good even after a 95 per cent. kill, and frequent applications of efficient toxicants can do no more than keep the incidence of the pest at a reasonably low level.

MOULTING

When a nymph reaches its limit of growth and is about to moult, it fixes its upper surface to the dome of the scale, using a secretion from organs called the Malpighian tubules. It then stops feeding, and remains motionless and seemingly dead for several days, while a new skin and a new rostralis are being developed. During this period it becomes much smaller than before, losing about 50 per cent. of its body-weight. When all is ready for the actual moult, the new rostralis is inserted into the host and then, by further shrinking, the insect separates itself from the old skin. This has become hard and brittle, and splits along its lateral margin. The dorsal portion is cast off and incorporated in the scale, while the ventral portion, which is very thin, remains underneath the insect. The old rostralis is left in the plant tissue.

The time required by the *Diaspinae* for moulting compared with that for feeding and development is unusually long among insects. At 28° C the first instar of the California red scale insect takes about 12 days for its complete development, during which it feeds for $3\frac{1}{2}$ days; 8 days are necessary for moulting. The second instar takes $3\frac{1}{2}$ days for
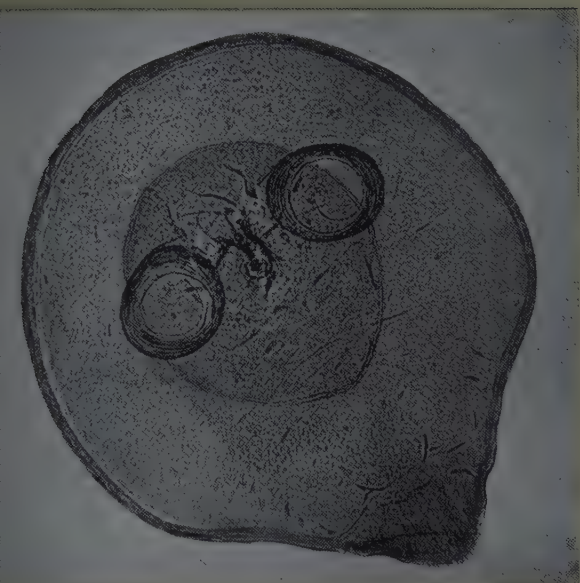
FIGURE 6 – *California red scale insect at time of the second moult, showing the new rostralis in coils, and the cast skin of the first instar.* (×130)
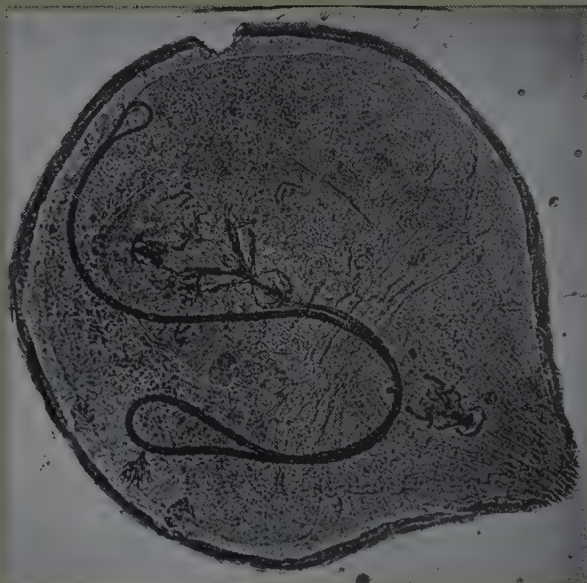
FIGURE 7 – *California red scale insect, showing the rostralis in loops ready for insertion, and shrinkage of the body.* (×130)

feeding and 6 days for moulting. These features have a direct influence on the vulnerability of the pest to insecticides. Throughout the moulting period, the insect does not feed at all and is therefore immune to the action of systemic insecticides. At this stage, too, the insect's body is covered by the old dead skin and so resists destruction by contact insecticides.

FEEDING HABITS

In habits of feeding, scale insects differ strikingly from their relations the aphids. The aphid normally inserts its feeding-tube into the phloem of the host plant and gets its food in solution by directly imbibing the sugary sap that is being translocated through the sieve-tubes. The scale insect, on the contrary, feeds exclusively on the contents of cells in the parenchyma, and the material has to be dissolved by external digestion before it can pass through the rostralis. For this reason, it seems likely that scale insect saliva is more active than that of aphids. It is far more injurious to plants, the saliva injected by the California red scale insect being so toxic that small plants are soon killed by a few insects.

The rostralis of the scale insect is a slender bristle formed by two pairs of extremely fine chitinous stylets. The inner pair of maxillary stylets cohere firmly along ribs on their inner surfaces, leaving two lumina, each of well under 1μ in diameter, between them. These form the suction and ejection canals. The outer or mandibular pair lie close against, but not attached to, the inner pair, and are used in conjunction with the inner pair for penetrating the plant tissue. In relation to the size of the insect, the rostralis is very long. In the first instar of the California red scale insect, for example, it is 0·33 mm in length, or 1·4 times as long as the body, and has a diameter of only $1·7\mu$; after the second moult it attains a length of about 3 mm, or 3–4 times that of the body, and its diameter increases to about $3·7\mu$. This long feeding-tube compensates the insect to some degree for its inability to move about in search of food.

Development of the rostralis can readily be traced in the body of an insect preparing to moult. The stylets develop separately and can be seen in pairs, each consisting of one maxillary and one mandibular unit, curling outward from the pharynx (figures 5 and 6). Here, there is a buccal
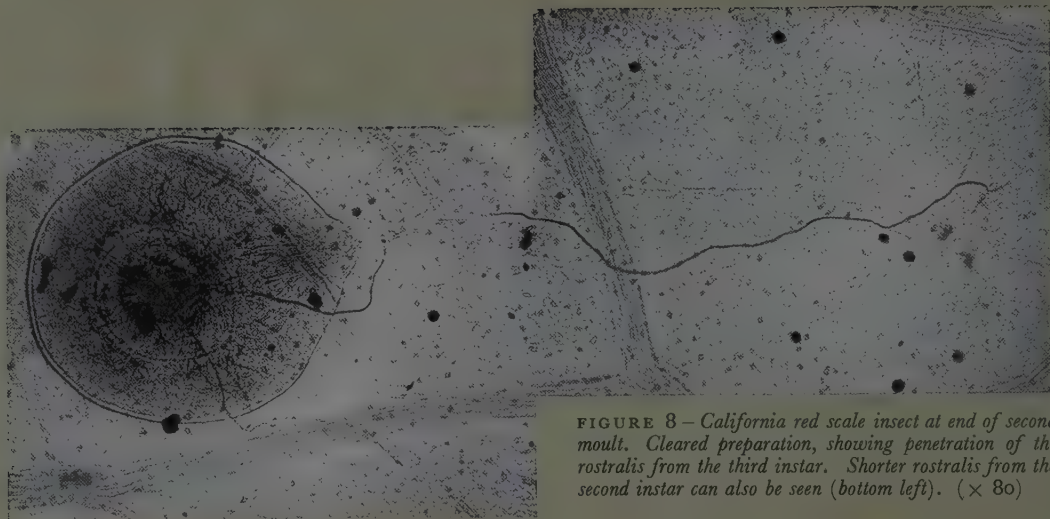
FIGURE 8 – *California red scale insect at end of second moult. Cleared preparation, showing penetration of the rostralis from the third instar. Shorter rostralis from the second instar can also be seen (bottom left).* ($\times$ 80)
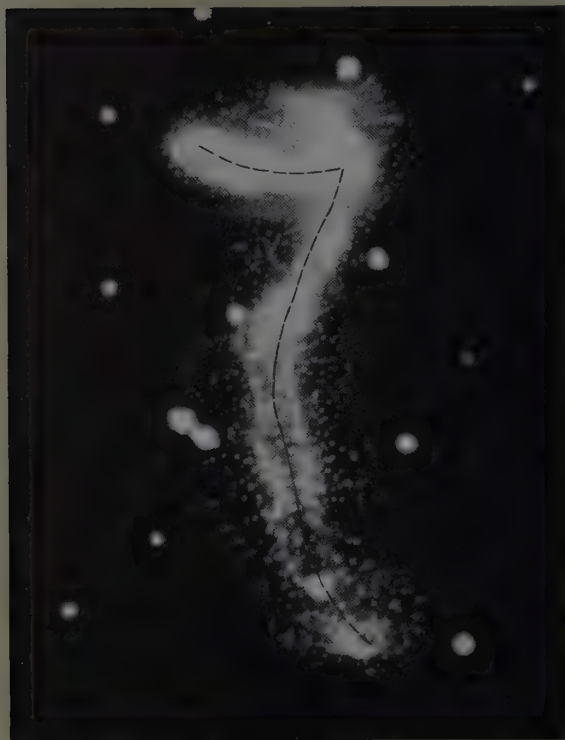
FIGURE 9 – *California red scale insect. Iodine preparation of a citrus leaf, showing disappearance of starch along the path of the second and third rostrales.* ($\times$ 30)

FIGURE 10 – *California red scale insect, illustrating method of transferring infestation from potato tubers to lemon foliage.*

frame consisting of four tubes, one for each stylet, and the stylets pass through these tubes before entering the pharynx. Muscles attached to each pharyngeal tube provide the mechanism by which the stylets can be separately advanced or withdrawn. In the mouth of the pharynx, the stylets meet to form the rostralis, and this organ now enters an elastic bag called the crumena, where it remains until required. Meanwhile it extends in length, and as it pushes against the enclosing walls of its container it is folded back into loops (figure 7). These loops have a distinctive shape in each different instar.

When a crawler has settled on its host, and before it starts to feed, the entire rostralis is coiled up within the insect's body; but when the organ is pushed further and further through the tissue of the host, the loops gradually unwind and the crumena becomes empty.

How this delicate organ can be extended and used to penetrate cell walls are problems that have long baffled the entomologist. According to Weber [4], who made his observations on the leafhopper *Psylla mali*, which has similar mouth-parts, penetration is achieved by a series of short thrusts. First one of the outer, mandibular, stylets is pushed slightly forward, then the opposite one for an equal distance, and finally the inner maxillary pair together. This sequence of movements continues until the organ is fully inserted. There is no reason to doubt that this also happens in the *Diaspinae*, though transmission of the muscle action from base to apex of a tube that is looped within the insect's body and bends about in the plant tissue is so remarkable that further explanation seems needed. The loops certainly play a part [1, 7]. It is also probable that saliva ejected through the tube aids penetration by softening the cell walls.

The path of the rostralis through the host can readily be followed, for saliva acting on the plant tissue coats the organ with a pectin-like substance, so that both the rostralis and its trace can be detected without staining in transparent preparations. Figure 8 clearly shows that the track of the rostralis is intracellular and fairly straight, but when the extending organ meets a hard obstacle, such as a vascular bundle, it is withdrawn a little and is pushed forward again in a different direction.

Feeding begins only when the rostralis is fully extended. Nevertheless, saliva is ejaculated with each forward step of the rostralis, diffusing into cells and hydrolysing their starch to sugar not merely in the immediate neighbourhood but for many layers around. This is readily demonstrated

by an iodine test, as depicted in figure 9. Predissolution of starch is also known to occur in the path of the hyphae of fungi [3]. Chlorophyll is sometimes destroyed in the zone of activity of scale insects (figure 1).

A pumping action is presumably needed for the ejection of saliva, though probably not for the uptake of food. Thus, if the rostralis is cut through while feeding is in progress, the end on the host side exudes a drop of liquid, indicating that the dissolved food rises under its own pressure.

The digestive system is highly specialized. Food from the oesophagus enters the ventricule, a blind sac, and thence diffuses into the body-cavity for further digestion. There, the Malpighian tubules, which communicate direct with the rectum, and the numerous silk glands excrete unwanted matter from the blood; but nothing is wasted in this insect's economy, and even the excreta are used for scale formation. The *Diaspinae* have no solid defaecation and they do not secrete honeydew—a wasteful process that seems to be associated with insects like aphids and mealy bugs which feed on the sugary sap of the phloem.

SCALE FORMATION

How the *Diaspinae* form their characteristic scale has not hitherto been described in detail. Entomologists seem to have been satisfied with the knowledge that the insect secretes a supposedly waxy substance from glands in its pygidium, and builds its scale with layers of this material and of the skins that are cast off at moulting. Few serious attempts have been made to explain the process, and not all of the findings can be substantiated.

As soon as the crawler has found a feeding-spot and inserted its rostralis into the tissue of the host, it starts to secrete fine white filaments, commonly called silk. This comes from glands scattered over the surface of its back, but chiefly around the pygidium, and it is forced out by periodical contractions of the abdomen. Secretion continues in this way for about half an hour, and thereafter, with each contraction, the abdomen is hitched over a little to one side, and left at a slight angle to the body when the pulsation has passed away. A fluctuating motion brings the rest of the body into line. As the contractions go on, therefore, the insect pivots round its rostralis.

It has been generally assumed from the work of Berlese [1] that the scale is formed by the insect repeatedly revolving around its point of attachment. This, however, would twist the rostralis, and careful observation has convinced the writer

that this does not occur. The movements do not continue in one direction, but are oscillatory. The crawler of the California red scale insect, for example, normally continues to turn over to one side until it has described an arc of 270–315°. It then turns back and, by alternately making sweeps to either side wide enough to overlap, forms a circular scale. The process goes on fairly rapidly. In 5 minutes, at 22° C, a first-instar larva of the San José scale insect secreted silk 0·2 mm long, undergoing 15 body contractions. In 35 minutes the same insect had made 140 contractions, which enabled it to revolve through an angle of 45°. At optimum temperatures the process is faster; the California red scale insect took only 20 minutes to describe an arc of 270°. Ordinarily, the scale of the first instar is completed in about two days, and the increments made by later stages take no longer.

In the early stages of silk-secretion, the legs are used as combs to catch the loose filaments and fasten them to the surface. Within a few hours, the insect is entirely covered with a circular tangle of loose silk, called the white cap. The Malpighian tubules then begin to secrete a glutinous liquid, which is forcibly ejected every 2–4 minutes and distributed by the same body movement as that already described. Much of this substance is absorbed by the silk, glueing these filaments into a soft and apparently homogeneous mass that subsequently toughens into the scale. This process may be likened to the bonding of fibrous material, such as fibre glass, with plastic to form a tough resistant product. The colour of the silk is changed by this impregnation from its original white to yellow, brown, or black according to species. Some of the liquid is also smeared on the surface under the scale, forming the white waxy deposit that is so conspicuous when a scale insect is detached.

The entire rim of the scale is so firmly stuck to the surface of the host that it is a puzzle to know how the insect sealed within contrives to breathe. The scale, however, is not quite airtight, and the insect has an unusually well developed respiratory system comprising four ventral spiracles (figure 11), and tracheae that ramify all over the body. How males gain access to the females is a problem that has not yet been solved. It is probable that, after its final moult, the female leaves a small unsealed gap in the rim of the scale.

Sometimes the Malpighian tubules of the young larva fail to function. The unimpregnated cap remains filamentous and white in colour, and heaps up to massive size. The insect dies before it can moult. No reason can yet be given for this.

On completion of the first moult, the old skin becomes embedded in the structure of the scale, making it firmer and less permeable. Thereafter the method of scale formation is rather different. The silk-secreting glands have increased in number, but they are now concentrated entirely around the pygidium, which is provided with comb-like hairs called palettes and a few highly chitinous, strong, sharp lobes (figure 11). The insect needs a bigger scale than before; as a step towards making it, it applies its lobes at a slight angle to the plant's surface and, with bulldozing movements, forces the old scale free, while adding new secretion beyond the rim. The freshly moulted nymph extends its reach by pulling out the rostralis far enough for its pygidium to define the limit of the new scale. Formation of the scale then proceeds much as before, except that the legless insect relies entirely on fluctuating movements of the body to pivot round the anchoring rostralis. Plant-hairs and dirt on the site are pushed away and become incorporated in the scale.

The last instar behaves in the same way, so that the final scale is a compact sandwich of the hardened secretions formed by each of the three stages, alternating with the cast skins.

Very little is known about the nature of the 'silk,' probably because this has been examined only in the completed scale. Berlese [1] refers to the filaments as silk. Maulik [2] states that the scale dissolves in a normal solution of caustic soda but is insoluble in concentrated sulphuric acid, Scales kept for a year in petroleum ether, benzene, alcohol, xylene, chloroform, acetone, carbon disulphide, and other solvents did not dissolve. Metcalf [5] states merely that the hard covering of the armoured scale insect is an intimate mixture of wax with some other material. Nel [6], Pesson [7], and Bodenheimer [8] mention wax secretion, but give no further details. The writer's observations on the San José and California red scale insects show that the filaments have a diameter of about 1μ, and are secreted dry and very firm. During any one larval period the filaments are secreted in a continuous skein. They cannot be detected by eye in the formed scale, yet their identity is not lost, and, if the binding material of a scale is dissolved by immersion for a few days in 10 per cent. caustic soda, the entire silk can be unwound in one long skein.

The silk glands, examined in the third instar of the California red scale insect, are long, slender organs occupying about half the body-length
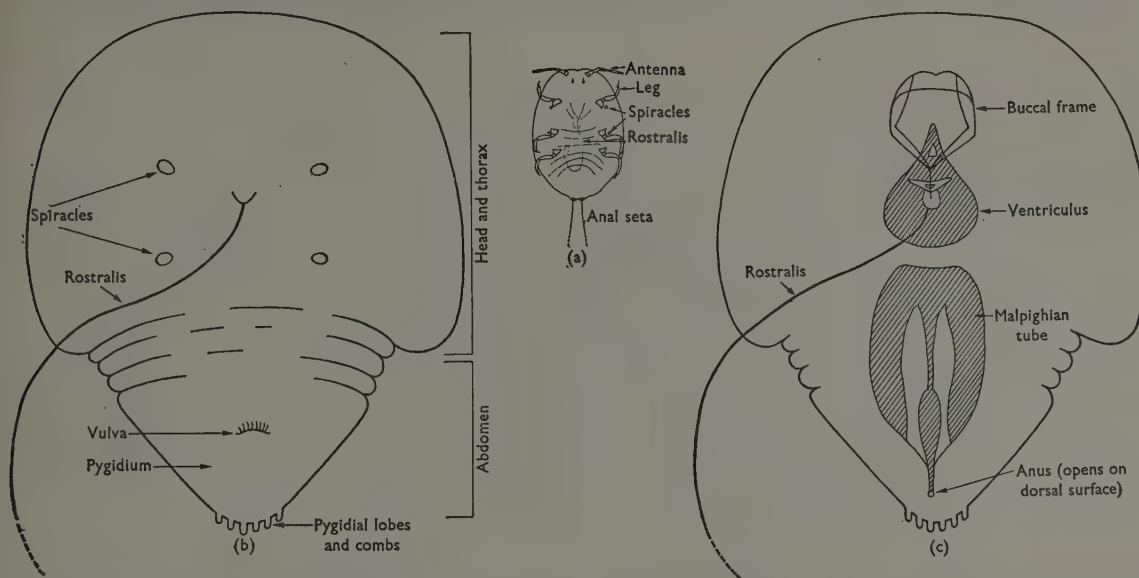
FIGURE 11 – *Scale insect, showing principal structures.* (a) *Ventral aspect of first instar (crawler) of* Quadraspidiotus sp. (b) *Adult female* Aonidiella, *showing external ventral surface.* (c) *Adult female* Aonidiella, *showing alimentary system.*

(figure 4). They number about 40, and their openings are arranged in a regular pattern on the dorsum of the insect around the apex of the abdomen; the pattern varies from species to species and is of great value in taxonomy. Each gland consists of a pear-shaped secretory cell prolonged as a narrow duct into a receptaculum, from which a short duct, having a lumen only 1 μ in diameter, enters a long tube, the macroduct that leads to the surface. Berlese [1] and Nel [6] describe and illustrate a pair of accessory glands, the ganogenes, supposed to give a superficial coat to the filament, but careful examination shows that these do not exist.

Although this study has cleared up several obscure features in the biology of scale insects it has revealed, rather than solved, difficulties in the way of control. Owing to the high specialization of the insects, it is very doubtful whether any generalized sorting-test can be relied upon to discover new scalicides. The laborious breeding of scale insects, which can be conveniently carried out upon potatoes (figure 10), must continue for test purposes, and the direct effects of chemicals must be estimated—a most difficult process. How progress can be made is not easy to say, but one of the first steps must be more research into the nature of these destructive pests.

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The production of diffraction gratings

L. A. SAYCE

Diffraction gratings are essential instruments in spectroscopy and in the many branches of science in which spectroscopic methods are applied. Until very recently, only one method of producing the gratings had any practical value, namely that introduced in the 1870's by H. A. Rowland of Johns Hopkins University. The need for larger and more accurate gratings, however, led Sir Thomas Merton in 1948 to suggest that gratings might be made as very fine screw-threads on cylinders. Dr Sayce explains how this fruitful suggestion was followed up, and describes the remarkable new gratings now becoming available.

A modern diffraction grating is a plane or spherical metal-surfaced mirror ruled with a large number of straight parallel grooves of predetermined cross-section. The number of grooves may be anything from one thousand to thirty thousand per inch, according to the purpose of the grating, but, whatever spacing is chosen, it must be maintained with the utmost regularity throughout the whole grating.

By ruling a mirror in this way its properties are profoundly altered, for whereas before the ruling process it deflected radiation of all wavelengths equally according to the laws of reflexion, it acquires, after ruling, the power of deflecting radiation to an extent governed by the wavelength and therefore of separating a complex radiation into its components. Diffraction gratings can thus replace prisms in spectroscopes, and for this purpose they have notable advantages. In fact, much of our knowledge of atomic structure has been derived from the use of gratings in the ultra-violet region of the spectrum, and their use in the infra-red region is now playing an essential and growing part in elucidating the structure of molecules.

The majority of the world's diffraction gratings have hitherto been ruled in America, by a method introduced in the 1870's by H. A. Rowland, of Johns Hopkins University. In England a ruling-engine employing Rowland's methods, built by Otto Hilger for the late Lord Blythswood, has been operated since 1908 at the National Physical Laboratory. A photograph and simplified diagram of this machine are shown in figure 1. It consists essentially of two slides or ways, at right-angles to one another, one to guide a carriage bearing the work and the other to guide the holder of the tool which inscribes the work. The work-carriage is pushed along by a lead-screw, bearing at one end a large ratchet wheel, the pawl of which turns the screw intermittently through a small fraction of a revolution during each cycle of operation. In the same period the tool-holder moves backwards and forwards along its slide, and the diamond tool itself is lowered into contact with the work while the latter is at rest.

Although this general principle of operation is commonly used in dividing-engines, peculiar difficulties arise in the ruling of gratings, owing to the need for unusual precision; engineering practice seldom needs an accuracy greater than 10^{-4} in, but the tolerance in the spacing of the grooves of a diffraction grating is of the order of 10^{-6} in. Spacing-errors of this magnitude may arise in a variety of ways: imperfections of the lead-screw, or of its thrust-bearing, and eccentricity of the ratchet-wheel give rise to periodic, or regularly recurring, errors which result in the characteristic 'Rowland ghosts'—faint subsidiary lines adjoining each true line of the spectrum (figure 2), which can cause much confusion. Other imperfections give rise to further 'ghosts,' and still others to random errors of spacing which can seriously reduce the resolving power. These random errors arise chiefly from the reciprocating action of the machine; it is impossible to maintain absolute constancy in the friction of the slides, and it is thus inevitable that variations should occur in the stressing of the moving parts and hence in their dimensions. These difficulties increase rapidly when the moving parts are made larger, and for this reason very few good gratings have been made with a ruled width exceeding six or eight inches.

The principal errors in gratings can be conveniently displayed by two searching tests. In the first, an accurate transparent replica of the grating is made, and this is divided into halves by a cut at right-angles to the grooves. The halves are then superposed, with a small angle between them and with the periodic error out of phase. The resulting moiré fringes running perpendicular to the grooves
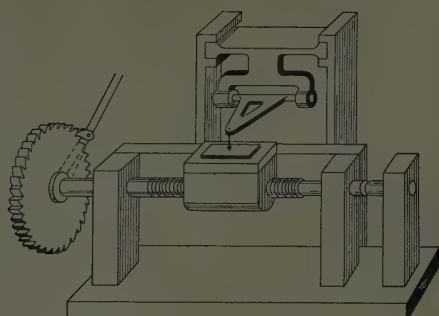
FIGURE I – *The Blythswood ruling-engine. A machine constructed by Otto Hilger, according to the principles laid down by Rowland, in which the grooves are ruled by an intermittent reciprocating action.* (a) *Diagram, greatly simplified;* (b) *photograph.*
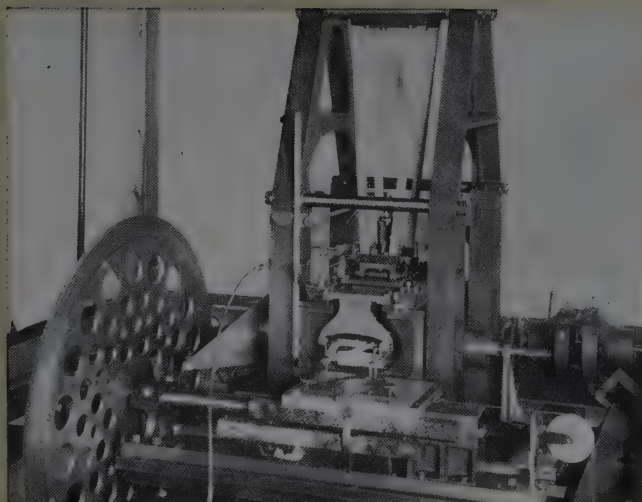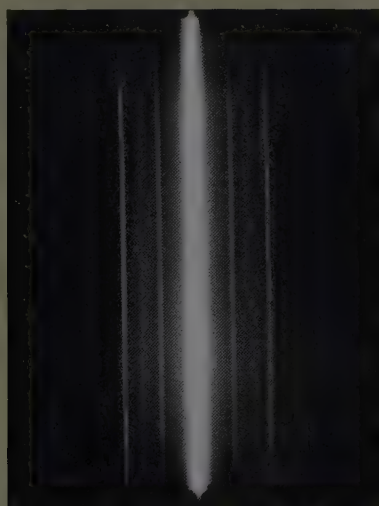
FIGURE 2 – *The green line of mercury, $\lambda = 5461$A, produced by* (a) *a recent Rowland grating of 7200 grooves per inch, and* (b) *a Merton-N.P.L. grating of 7500 grooves per inch.*

FIGURE 3 – *A plane grating of 7200 grooves per inch, ruled on one of the Rowland engines at Johns Hopkins University.* (a) *Moiré pattern and* (b) *interferogram of the first-order wave-front.*
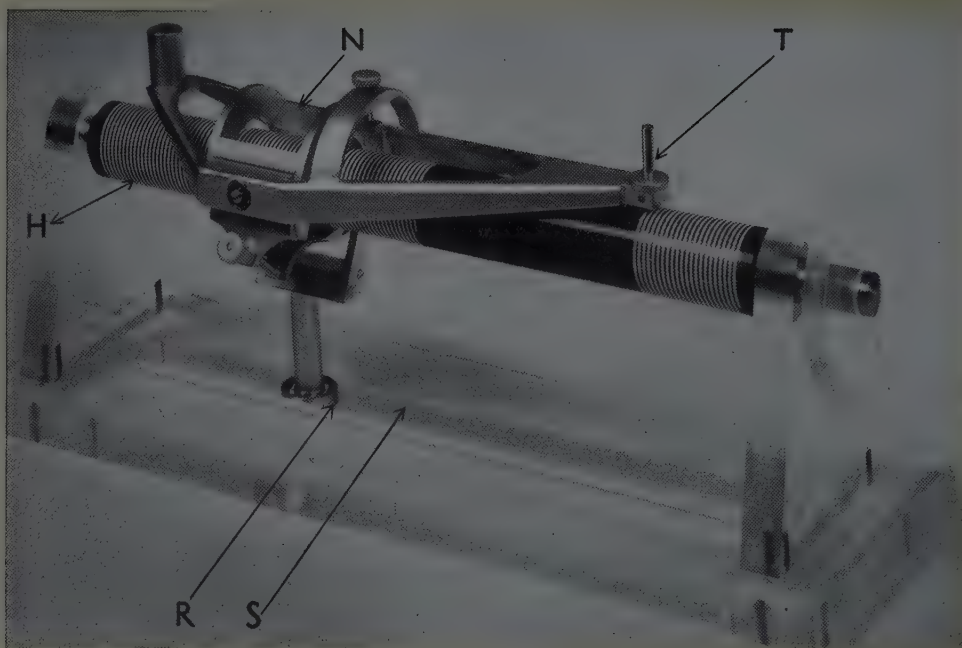
FIGURE 4 – *A model of the Merton nut device for producing a 'secondary,' corrected, helix from a 'primary' lathe-cut helix.*
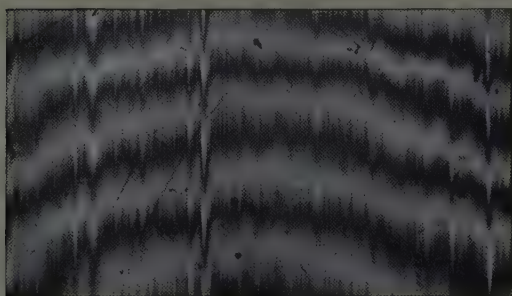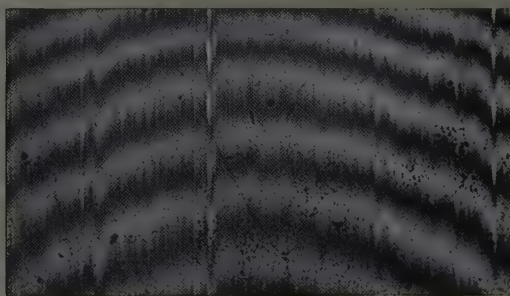
(a)   (b)

FIGURE 5 – *Interferograms of the first-order wave-front of* (a) *a Blythswood grating and* (b) *its Merton-N.P.L. replica.*
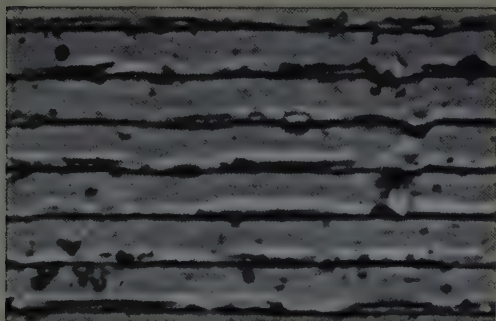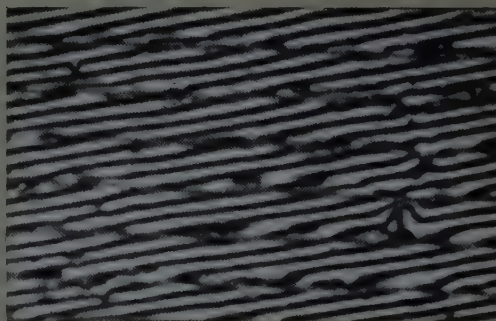
(a)   (b)

FIGURE 6 – *Micrograph and micro interferogram of a 'blazed' ruling.* (× 750)
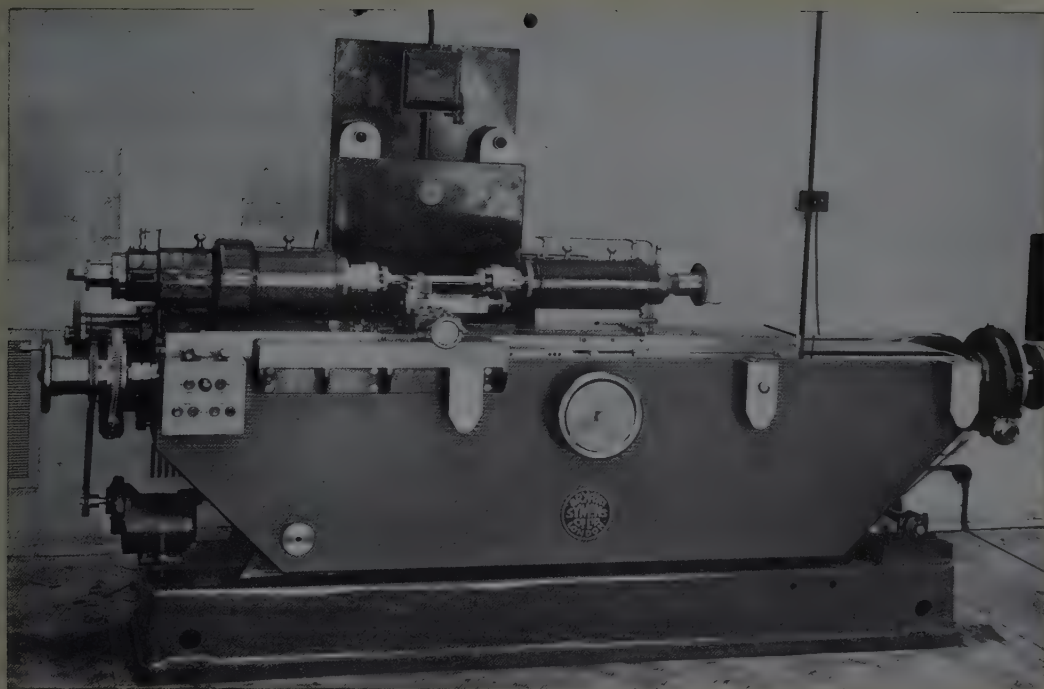
FIGURE 7 – *A lathe specially built for the production of primary helices up to 30 000 turns per inch.*

(a)
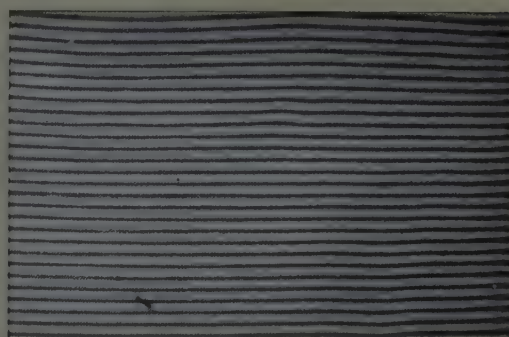
PRIMARY HELIX   SECONDARY HELIX

(b)
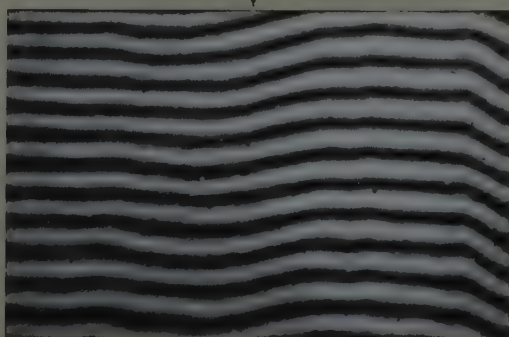
FIGURE 8 – *Proof of the corrective action of the Merton nut given by* (a) *moiré patterns and* (b) *interferograms of first-order wave-fronts of replicas derived from primary and secondary helices respectively.*

show clearly the periodic errors of the grating. In the second test, one of the diffracted wave-fronts of the grating is made to interfere with the reflexion from a truly plane surface in a modified Fizeau interferometer. Under these conditions, the errors in spacing of a defective grating show up as departures from the straight and parallel interference fringes which would characterize a perfect grating, and the test is particularly valuable in showing the exact location and extent of the defects. Examples of the application of each of these tests to a grating of the Rowland type are shown in figures 3(*a*) and 3(*b*).

During recent years, a great increase in the world demand for larger and better diffraction gratings has led to the construction of a number of new ruling-engines, but all of them resemble those of Rowland in ruling the grooves one by one by a reciprocating action resembling that of the engineer's shaping- or planing-machines.

In a machine aiming at a precision of a micro-inch there seems something fundamentally wrong in thus constantly stopping, starting, and reversing its essential parts, for at this scale of accuracy small stresses and vibrations which can safely be ignored in engineering practice become of vital importance—it is as if even steel had the properties which we normally associate with rubber. Considerations such as these led Sir Thomas Merton in 1948 to suggest that gratings be generated on cylinders as very fine screw-threads, so replacing the intermittent and reciprocating actions of previous ruling-engines by a smooth and continuous lathe-like movement and producing the whole of a grating as one long groove. Such a helical grating could be used in a spectroscope only if it were made to give a plane wave-front, but this could be done in several ways. First, the helix could be arranged with its axis coincident with the line focus of a cylindrical lens. Or, secondly, if the grating were required for use in a region of the spectrum to which the lens was not transmissive, it could be arranged at the focus of an off-axis cylindrical parabolic mirror. Neither of these methods is easily practicable, however, because really good cylindrical lenses and mirrors are very difficult to make. Merton proposed, however, a third possibility: that the helix be coated with the solution of a plastic which would harden to an accurately fitting skin or pellicle. This tubular pellicle could then be slit longitudinally, unwrapped from the helix, and opened out upon a flat surface of moist gelatine which on drying slowly through the pellicle would be per-

manently moulded into a copy 'in the flat' of the original helix. The gelatine copy could act as a transmission grating or could be given a vacuum coating of aluminium to make it a reflecting grating. This plastic copying process was especially attractive, for it could be applied repeatedly to the original helical ruling and thus provide an indefinite number of identical copies, so making good gratings both plentiful and inexpensive.

In developing these suggestions at the National Physical Laboratory, attention was first directed to the copying part of the process. For ease of comparison we took a plane grating, ruled on the Blythswood engine, as a master, and tried to make accurate copies of it. There were two principal difficulties to be overcome: first, to prepare a pellicle that would, to the extraordinary precision required, preserve throughout the process the exact proportions of the master grating; secondly, to prepare an optically flat surface of gelatine which would on drying retain its general flatness while at the same time conforming accurately to the groove-form of the pellicle in contact with it. That both these difficulties have been overcome is illustrated in figure 5, which shows interferograms of the first-order wave-fronts of a master grating and of its copy. The master grating was an imperfect one full of periodic and random errors, and for this reason it shows all the more clearly the fidelity of the copying process: every imperfection is faithfully reproduced. The procedure which led to this result has been fully described elsewhere [1], but it may be stated here that we use pellicles made of polymethylmethacrylate or polystyrene, annealed upon the master grating and transferred to thin gelatine layers cast between optically flat surfaces.

Being thus assured that we had an adequate copying process, we next turned our attention to the preparation of the helical gratings themselves. It is not especially difficult to adapt a precision screw-cutting lathe to cut very fine screw-threads if the lead-screw is made to turn very slowly by means of a suitable train of reduction-gearing, and in this way it was found possible to produce helices of up to 15 000 turns per inch. Such lathe-cut helices were, however, quite unsuitable for use in making gratings, for they possessed considerable periodic errors derived from inevitable defects in the lead-screw, its thrust-bearing, and its gearing, which would cause the spectrum to be completely marred by false lines or ghosts.

Merton has, however, shown how to lay the ghosts of helical gratings by a very simple and

ingenious device, of which a model is shown in figure 4. Suppose we take a polished metal bar and cut upon one half of it a fine helix, H, by means
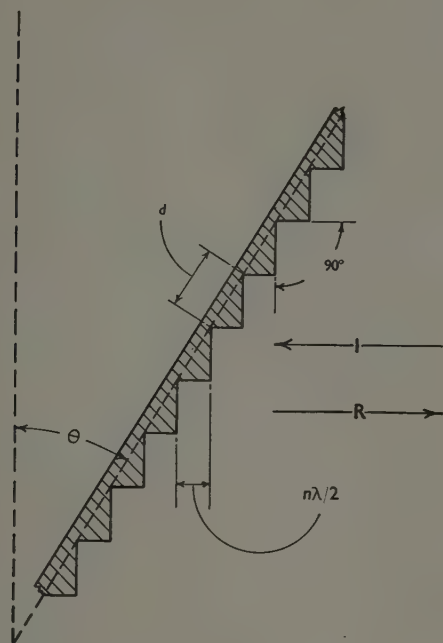
FIGURE 9 – *The action of a 'blazed' grating.*

of the converted screw-cutting lathe. When the bar is rotated between centres and provided with a nut, N, restrained from rotation by a roller, R, and straight-edge, S, the nut will travel along the helix, and a diamond tool, T, attached to it can be made to copy the helix upon the other half of the bar. The nut, N, is not an ordinary nut, but is lined by three strips of a resilient material such as pith, and being pressed firmly into the grooves of the helix always fits it perfectly. The result of this simple arrangement is that the periodic errors of the screw are averaged out, the nut as a whole moves with perfect regularity, and the diamond tool cuts a secondary helix without any periodic error. A grating made from this corrected thread therefore gives spectra that are entirely free from ghosts.

Evidence that the Merton nut does in fact perform in this way is provided by the moiré fringes in figure 8(a), which (left) shows fringes derived from crossed replicas of a primary lathe-cut thread, and (right) shows those similarly derived from the secondary thread. If further confirmation were needed, it is given by the

Fizeau interferograms of figure 8(b), which were produced from accurate plane replicas made from the same primary and secondary threads. It is interesting to see that the Merton nut is competent to deal both with the periodic errors of the lathe-cut thread and with the more local of its errors of run. Such curvature as persists in the fringes of the secondary thread are produced by very gradual changes in spacing due to defects of the lathe lead-screw—the sort of defects, however, which can be put right by means of the corrector-bar commonly provided on precision lathes.

So far we have considered only the accurate positioning of the grooves of a diffraction grating. This is the requirement upon which its resolving power primarily depends, but there is another consideration which is often just as important: its photometric efficiency. Incident energy is diffracted by a grating into a number of orders, but as only one of these orders can be used at a time the energy in all the unused orders is wasted. This may not matter greatly where there is plenty of incident energy, but it is of vital importance to the astronomer or infra-red spectroscopist, who has to do with very little. Fortunately, it has been found possible to control the distribution of energy in the various diffracted orders—an operation which R. W. Wood called 'blazing' a grating—by controlling the shapes of the grooves. Thus where a plane grating, used in the well-known Littrow condition, receives incident energy in the direction I (figure 9), energy of wavelength λ will be returned most strongly in the required direction R when the incident beam is normal to a series of plane surfaces separated by steps of $n\lambda/2$, where n is a whole number equal to the order of diffraction. A grating having flat-sided grooves of this kind has many of the essential properties of an echelon and is often called an echelette. Its difference from an echelon lies, of course, in the fact that, possessing a vastly finer spacing, the steps are far shallower, and it is used therefore in a far lower order of diffraction.

Evidently, the ideal groove-form for any grating to be used in a Littrow mounting is a right-angled saw-tooth in section, the angle θ of the tooth to the mean surface of the grating depending upon the spacing interval d and the order n requiring reinforcement in accordance with the formula $\sin \theta = n\lambda/2d$. The extent to which this ideal can be approached depends upon two factors: the ruling-tool and the material being ruled. The ruling-tool is made from an octahedral crystal of diamond, shaped in such a way as to produce two

highly polished surfaces intersecting at right angles in a direction in which the edge is least susceptible to abrasion. This edge cannot be made infinitely sharp; it has a small but finite radius of curvature. The bottom of each groove of the grating is therefore rounded off slightly by an amount that, in the finest rulings, is an appreciable fraction of the groove spacing. This is one reason why it is more difficult to produce strong blaze in fine rulings than in coarse ones.

In considering the influence of the material of the blank upon the blaze of a grating it is important to remember that the groove is not cut as by an ordinary lathe tool, but is formed by the pressure of the diamond edge acting tangentially to the cylinder. If the original surface is quite smooth and uniform in hardness it is then possible to obtain a groove of great regularity. But there is a complication: the material displaced from the groove is not got rid of as a shaving but is pushed up into ridges at each side of the groove. One of these ridges is upon the hitherto unruled portion of the blank, but the other is deflected towards the side that is already ruled, and thus tends to alter the shape of the preceding groove. By careful adjustment of the pressure of the tool, however, it is possible to restrict this distortion to one side only of the groove, leaving the other, undistorted, side to act as the effective diffracting surface. A magnified portion of such a grating is shown in figure 6, where (a) is an ordinary photomicrograph and (b) a microinterferogram showing that the surface consists of a series of escarpments. When used in a Littrow mounting, the diffracted energy of the required spectral region is concentrated into one order. The production of echelette gratings is not, of course, a monopoly of the Merton-N.P.L. process, for the idea was suggested and applied by R. W. Wood as long ago as 1913, but the concentration of energy in a required direction is, in our experience, more easily controlled when the grating is generated as a helix than when it is ruled by the traditional ruling process.

Hitherto our experiments at the National Physical Laboratory have been of an exploratory character and have been made, for simplicity, upon cylinders 1 inch in diameter yielding plane gratings with grooves about 3 inches long. Even these experimental gratings have, however, proved particularly useful in infra-red spectroscopy, where their performance has far surpassed that of the expensive prisms of calcium and lithium fluorides used in conventional spectrometers. Our main limitation so far has been in the lathe used for cutting the primary helix, but this is now being replaced by another specially designed for the work. The new lathe (figure 7) has been made to an extraordinarily rigid specification, and is intended to produce helices having up to 30 000 grooves per inch upon cylinders up to 4 inches in diameter. Accurate ghost-free plane gratings with a square foot of ruled area are thus our ultimate objective. Whether we shall ever succeed in realizing it remains to be seen, but if we do we shall have gone far beyond the achievements of the reciprocating process which has supplied the world with gratings for over seventy years.

REFERENCES

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DEW, G. D. *J. sci. Instrum.,* **29**, 277, 1952.

Book reviews

The last forty years have seen a shift in the interrelations of the educational and intellectual activities commonly classed as the sciences and the arts. The change has been gradual but the cumulative result is revolutionary—and the revolution is not yet complete. In Britain before the first world war the disciplines in the universities had a long-accepted order of precedence in which the arts took a place distinctly above the sciences. Moreover, for important administrative positions, as for higher posts in the civil services, special weight was always given to proficiency in the languages, literatures, and philosophies of ancient Greece and Rome. In other countries the situation was very similar. Thus humane studies both suffered from limitation of scope and, at the same time, were accorded an academic prestige denied to any but the very highest scientific achievement. In fact, the status of the classics in the decade after 1900 did not greatly differ from that in 1500. Higher education was still strongly reminiscent of what it had been in Renaissance times.

We know now, from the course that events have since taken, that the sciences could well take care of themselves, for they have become the main determinants of the pattern of our life. Therefore their relatively inferior academic status, now largely righted, would have been of but temporary importance had there been some accepted intermediary between the sciences and the humanities, some recognized discipline partaking of the nature of both. Unfortunately, passage from one to the other was difficult. The intellectual world became a fragmented world, for there were no bridges between its parts. To build them has taken full forty years, and no man has had so significant a share in that task as George Sarton.

To it he has dedicated all his powers. He founded the two journals 'Isis' and 'Osiris,' and has edited and partly written no fewer than fifty-five volumes of them, besides writing many ancillary volumes and notably his enormous and indispensable 'Introduction to the History of Science.' This last work is a most carefully reasoned, detailed, and critical bibliographical record of the achievements of science over at least two millennia. Its reliability and its systematic arrangement have made it a model for all comparable undertakings.

Sarton has thus become the acknowledged authority on the history of the process by which the human mind became first coherent, then rational, then experimentally disposed, and of the knowledge that it has achieved with its coherence, rationality, and experimentation. His studies transcend the sciences, the humanities, and in a sense even the philosophies, and place him among the great teachers of our age. His retirement last year from his chair at Harvard was an important event in the world of learning, for it has given him time to consolidate and synthesize the great mass of learning which he and his followers have accumulated. He has now issued the first of eight volumes of what he calls a 'History of Science.' The title may mislead some readers, for it contains far more than the phrase implies. It is nothing less than an attempt to give an account of the evolution of the rational mind and of its works. He comprehends in his survey not only what is usually called science, but also historiography, much philosophy, exploration, logic, and many other activities which, for one reason or another, have made their impact on science. He is thus doing much to bring together studies that have long dwelt in widely separate departments, and is attempting, we believe successfully, to arrest and heal the fragmentation of our intellectual world. And more: his work, when completed, will itself be equivalent to a philosophic system of a new and highly original order.

It is here perhaps in place to give our readers some idea of Sarton's primary intellectual equipment. Born in 1884 at Ghent and educated there, he spoke French in the first place, but early acquired an expert knowledge of the main European languages. He had a good classical education but took his doctorate in the physical sciences. He

has always shown a strong linguistic bent, and his medieval studies soon led him to add Arabic and Hebrew to his armoury. With complete command of English, acquired long before he settled in the United States, he wields an individual style which occasionally has a pleasantly rarefied Gallic aroma, well brought out by a gentle, humane, but sometimes slightly sardonic humour. Above all his writing is individual, challenging, thought-provoking, and readable. Not to read part at least of what he writes is to miss some of the best rewards which a scientific training provides.

During the last twelve months he has produced two volumes, either of which would alone attract to himself the notice of the learned world. His 'Guide to the History of Science' has prefixed to it essays on science and tradition which set out his general standpoint. The rest of the work is bibliographical in the widest sense. It is not only a very carefully selected and arranged list of books on the subject, but evaluates the books so that nothing is here without good reason. Moreover, there are large sections on institutions, congresses, and other organizations that busy themselves with the history of science and with its relations to the humanities.

It is difficult, in a few words, to do justice to the most heroic of his enterprises, the great 'History of Science.' Its nature will become clearer as the results crystallize. The work will seek always to display the growth of the human spirit in its natural background. 'The spirit,' as he says, 'is always influenced by the background, but its originality and integrity are in itself.' Ideas are never completely independent and original—they could not be so, since man, of all beings, is the most fundamentally social—for ideas 'hold together and form chains, the golden chains that we call traditions.' It is perhaps the essence of Sarton's message that science, no less than the other great activities of the human spirit, is not so much bound by tradition as itself a tradition, which he seeks to trace with unique acumen and skill. The tradition of science provides not only a way of looking at our universe but a moral code expressed in the observer's attitude toward phenomena. Science is for him a vocation which must affect every aspect of life and every attitude towards life.

This first volume is divided into three

parts, the first on oriental and Greek origins, the second on the Greek achievement of the fifth century B.C., and the third on that of the fourth century B.C. Of these, the first is the most tentative and is likely to be of less permanent value than the others, since knowledge of the period is advancing with great rapidity. For this reason the material that it presents submits less readily to Sarton's constructive and synthetic genius. The second and, especially, the third parts are more typical of the man. The findings of the volume as a whole are best summarized in his own words:

'Looking backward, either from the year 300 B.C. or from the more enlightened (?) year of grace A.D. 1950, the greatest achievement, the climax, of the enormously long period that this book has covered seems to be the Aristotelian synthesis. The greatness and wisdom of that synthesis appear equally well whether one considers it against the background of the Greek past, brilliant and adventurous, artistic, lyrical, scientific, or from the point of view of the many-sided discussions that agitated Greek minds during the short twilight of Hellenism.

'Aristotle had put in good order the knowledge then available in astronomy, physics, zoology, ethics, politics, but in addition he had built up a philosophy that was well documented, rational, and moderate. He established the *via media* that can be traced after him across the ages down to our own day, the *via media* that was followed in the course of time by many Muslim and Jewish philosophers, by St. Thomas, the neo-Thomists, and many Jesuits, as well as by the majority of the men of science. The history of that middle road includes a large part of the history of philosophy and of the history of science; to put it otherwise, when one contemplates the history of science in its wholeness, one can see very distinctly that road passing through it, right in the middle of it, from the fourth century B.C. to the twentieth after Christ.'

Dante called Aristotle 'the master of those who know.' Sarton, who comes some 2300 years later, is among the rare few who are not wholly unworthy of that title, for he seeks to bring into the world of thought a unity which it had lost.   CHARLES SINGER

THE FOUNDER OF MODERN CHEMISTRY

Antoine Lavoisier: Scientist, Economist, Social Reformer, *by Douglas*
McKie. *Pp. viii + 335. Constable and Company Limited, London.* 1952. 30s. *net.*

A full and authoritative account of the life and work of Lavoisier has long been desired, not only by chemists but by all those interested in the history of the eighteenth century. That we have had to wait for it until now is partly to be explained by the fact that Grimaux's book on Lavoisier, published in Paris in 1888, proved another example of the rule that the good is enemy of the best: Grimaux did his work so well that historians felt there was little more to be said. More curious inquirers could not wholly subscribe to this opinion, and the desirability of further research on the subject gradually became obvious. Many scholars might have been deterred by the magnitude of the task, for, in spite of his short life, Lavoisier himself wrote enough to fill six large quartos, and there is a voluminous contemporary and later literature concerning him. To make a careful study of all this material required determination, and we must be grateful that it was undertaken, and brought to a highly successful conclusion, by Dr McKie, whose scholarly researches on the history of science are so deservedly esteemed.

Lavoisier's contributions to chemistry are of course well known, and the chemical sections of this book contain few new facts; what, however, will be of considerable interest to chemists is the critical appraisement that the author makes. One naturally turns to his judgement on the water controversy, which still flares up from time to time. Here he is emphatic that the facts are plain: Watts' ideas were confused, and he has no claim to have discovered the composition of water. Cavendish, who obtained water by exploding a mixture of inflammable air and dephlogisticated air, thought that the water was previously present in both airs. Lavoisier maintained that water was a compound of the two airs, and confirmed his view by decomposing water into them. The honour of the discovery is therefore undoubtedly Lavoisier's.

Though Lavoisier's position as the founder of modern chemistry is not contested, less is generally known about his public life as a liberal economist and social reformer. Dr McKie gives us a full and very interesting account of this side of Lavoisier's career, set skilfully against a background of the French political scene. It is clear that a great deal of reading of original sources was entailed here, and McKie's long studies
of eighteenth-century France have been fruitfully applied. All chemists interested in the history of their science—and that should be all chemists—ought to read, and preferably to possess as well, this valuable monograph. As a final word, it may be mentioned that the book contains a reproduction of a recently discovered portrait of Lavoisier painted about 1778-9 by an unknown artist.   E. J. HOLMYARD

CHEMICAL CONSTITUTION AND BIOLOGICAL ACTIVITY

Chemical Constitution and Biological Activity, *by W. A. Sexton. Pp. xxiii + 424. E. and F. N. Spon Limited, London. Second edition.* 1953. 60s. *net.*

The first (1949) edition of this book was favourably reviewed in ENDEAVOUR in 1950 (9, 158), but the subject continues to advance so rapidly that the appearance of a new and enlarged edition after the lapse of only four years is to be welcomed. Since the book is already so well known to all biochemists, it would be superfluous to add further commendation, and we may confine ourselves to mention of the changes made. This second edition takes into account work published up to the end of 1951, with a few additions concerning later work made while the book was in the press. The principal alterations concern the biochemistry of the purines and pterins, the mechanism of transmethylation, the new antimalarial substances, naturally occurring antibiotics, organo-phosphorus insecticides, and cancer and plant-growth regulators. The author's pleasant and lucid style enhances the fascination of an intrinsically fascinating subject.

THE SEA

La Mer, *edited by V. Romanovsky, C. Francis-Bœuf, and J. Bourcart. Pp. 503, with numerous illustrations. Librairie Larousse, Paris.* 1953. Fcs. 5200 (reliure 'éditeur'), 7150 (reliure 'amateur').

Although this is not a strictly scientific work—containing as it does chapters on such general subjects as legends of the sea, the design of ships and ports, sailing, and diving and submarines—there is nevertheless much of interest to the general scientific reader, reflecting the editors' interests in oceanography and marine biology. There are, for example, chapters on the properties and industrial use of seawater; on the movements of the sea— waves, tides, and currents; on marine

life, both animal and vegetable; on deposits on the sea bed; on charts of all kinds; and on coast erosion. These subjects are most clearly discussed and illustrated with a wealth of well chosen illustrations in the Larousse style. This is a most interesting book and a mine of information about marine matters of every kind; it deserves to be widely known.   TREVOR I. WILLIAMS

THERMODYNAMICS

Thermodynamique, by Y. Rocard. Pp. 551, with line diagrams. Masson et Cie., Paris. 1952. Paper covers, fcs. 3650; boards, fcs. 4150.

This book gives a comprehensive account of thermodynamics. It opens with a discussion of the fundamental laws. This is followed, first by an account of those properties of physical and chemical systems about which thermodynamics offers a pertinent diagnosis, and secondly by an up-to-date account of engineering applications. This section includes accounts of turbines and of jet-propulsion. Sections follow on radiation, kinetic theory, statistical mechanics (including quantum statistics), and irreversible processes.

Throughout the book, phenomena which are of current interest are examined. For example, the author gives an account of order-disorder phenomena in alloys, and of phase equilibrium in binary systems. On the other hand, the accounts of some classical topics are rather out of date. For instance, the Debye theory of the specific heats of solids is presented as though it were the final word on the subject: the present reviewer looked in vain for any account of the lattice theory of specific heats and of the light it sheds on the inescapable shortcomings of Debye's approach to this topic. In his discussion of the Nernst heat theorem the author does not mention the specifically low-temperature phenomena—the solid-liquid transition in helium, the transition of a superconductor in a magnetic field, and adiabatic demagnetization. As these phenomena provide the most striking and convincing evidence in favour of the Nernst theorem it is unfortunate that they are not mentioned in this connexion.

The book assumes a previous acquaintance with the elements of thermodynamics. The reader who is so equipped will find it interesting and stimulating.   A. R. MILLER

CHEMISTRY OF HYDRIDES

An Introduction to the Chemistry of the Hydrides, by D. T. Hurd. Pp. x + 231. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London. 1952. 44s. net.

The hydrides of the elements are compounds of growing technical importance and considerable academic interest, and it is surprising that the first monograph covering such an attractive field has but recently appeared. The present author has the advantage of extensive experience of both the technical and academic aspects of the chemistry of the hydrides.

In the preface, he expresses his intention of supplying a critical and coordinated presentation of the theory, properties, and reactions of the hydrides. The familiar and extensively studied hydrides, such as water and ammonia, are discussed only so far as is necessary to relate them to the less familiar substances. None the less, the book creates the impression that much has been sacrificed to condense the material into two hundred and thirty pages. As a result, it is too superficial to satisfy readers already acquainted with this field, and yet unsatisfactory for those less specialized.

The inclusion of chapters on simple theoretical concepts concerning the different kinds of chemical bonds and the nature of acids and bases seems unnecessary. The space would have been better employed in a more detailed treatment of individual hydrides or in the discussion of less commonly known, but equally relevant, theoretical topics, such as the nature and origin of non-stoichiometric compounds. Physicochemical detail is sparse, and even the extensively studied palladium-hydrogen system is dismissed in a page.

The systematic description of the hydrides follows the usual classification: ionic, covalent, and transition element hydrides. The first two classes are subdivided for convenience according to the groups of the periodic classification; some obscure hydrides, such as those of copper and zinc, are collected into a separate chapter at the end. A short selection of references follows the description of each compound. This systematic treatment is followed by a chapter on nomenclature and by five appendices. Three of these—referring to the deuterides, the toxicology of the hydrides, and vacuum manipulation of volatile compounds—would have been better omitted, since they are too brief

to be useful. The descriptive chapters contain some minor errors of fact and a few inconsistent statements. Several interesting applications of established or potential industrial importance are included; some of these have not previously been described outside the patent literature.

The critical evaluation of the experimental data is less satisfactory. This is particularly noticeable in the chapter discussing the hydrides of the transition elements, where little attempt is made to identify the phases which occur in the different metal-hydrogen systems.

The book is well produced, possesses adequate author and subject indices, and is reasonably free from typographical errors.   A. G. MADDOCK

CARTESIAN PHILOSOPHY

Diderot and Descartes: a study of Scientific Naturalism in the Enlightenment, by Aram Vartanian. Pp. 336. Princeton University Press, Princeton, New Jersey; Geoffrey Cumberlege, London. 1953. 40s. net.

The aim of this work is to show how the Cartesian philosophy, despite the spiritualist metaphysics on which it was originally based, became the source of the materialist doctrines taught by the French encyclopaedists of the eighteenth century. The ultimate reason for this development is traced to the change made by Descartes in the relation between theology and natural philosophy. His predecessors had inferred the existence of God from the study of nature and of causality in the external world: Descartes reverted to the ontological proof, which ignored sense-experience, relying instead solely on the theological consequences of certain innate ideas. A significant consequence of this metaphysical scheme was that it rendered the domain of physics unrelated in any fundamental sense to theological or religious problems. It differed moreover from the corpuscular physics of Epicurus and Democritus in being free from the concept of chance: and indeed it was, at any rate as developed by Fontenelle, a really 'scientific' materialism: all phenomena were traced to the ultimate postulates of matter and its necessary motions, which thus became the starting-point of natural philosophy, without being further related to a cause outside and above nature. The book treats its subject at perhaps undue length, but it is clear and interesting.

EDMUND WHITTAKER

PRIMITIVE MEDICINE

Catalogue of an Exhibition illustrating the Medicine of the Aboriginal Peoples in the British Commonwealth, *with an Introduction by E. Ashworth Underwood. Pp. xviii + 58. Oxford University Press, London. 1952. 3s. 6d. net.*

Scientists often forget the human incapacity to dispense with older modes of thought, even when developing new ones. Myth and its brother magic survive lurking in some nook in all our minds, for mind is much wider than mere understanding, and it is that special myth-making property of mind which we call imagination that alone can generate problems for the understanding to work upon. Thus it is well not to be too contemptuous of the magical element in the medicine of savages and barbarians. Dr Underwood has under his care, as Director of the Wellcome Historical Medical Museum, a very large collection illustrating primitive beliefs and practices. In this finely illustrated catalogue he details some six hundred objects from that collection. A satisfactory classificatory system of primitive medicine is almost impossible, because rational elements take but a minor part in it, and the frontiers that separate it from ordinary affairs are indefinite. Some of the headings of the catalogue give, however, a general idea of the nature of the exhibition, e.g. pictography, anatomy, spirits of disease, breach of tabu, cult of the god of smallpox, the medicine-man and his equipment, surgery, bodily deformations, drugs, poisons, protective appliances, personal hygiene. The topics that have lent themselves best to illustration are trephining, blood-letting, removal of foreign bodies, deformations, tattooing, child-birth, and amulets. Both exhibits and catalogue are well worth the attention of anthropologists, ethnologists, and those interested in the psychology of peoples of the lower cultures.   C. SINGER

CYBERNETICS

Cybernetics, *edited by Heinz von Foerster. Pp. 240. Josiah Macy Jr Foundation, Caldwell, N.J. 1952. $4 net.*

The increasing difficulty of explaining the discoveries of one science to those who follow the discipline of another—or who follow none at all— has led to a recent interest in breaking down the barriers between the compartments of knowledge. One way of studying this question of communication is to bring together men who study the theory of knowledge, the properties of the mind, and the behaviour of human beings and other animals, and to encourage them to communicate on this question. The results and the means of such communication were in 1949 given the name 'cybernetics,' and the proceedings of the 8th Conference on the subject are now available.

At this meeting twenty experts, mostly social scientists, discussed six discourses which are in some way connected with communication. The report is apparently almost verbatim. The unanswered questions, the ignored interruptions, the self-questionings and disagreements, appear in bulk. The editor's claim to have produced a somewhat unusual document is thus certainly justified; his claim to have avoided a 'Babylonian confusion' is not, however, equally admissible. The discussions show a physical and biological problem in process of being adopted by social scientists, a process which tends to confuse any scientific statement.

In the introduction, the view is expressed that 'a social system in equilibrium . . . defied analysis until the simple notion of one-dimensional cause-and-effect chains was replaced by the bi-dimensional notion of a circular process.' This is an original and ostensibly fundamental statement. But is it true? Is a circular process two-dimensional? And are the cause-and-effect chains of genetics one-dimensional? The relationship of the individual to the community is the root of all communication. It is a genetic relationship. But is it so simple?

These questions were not asked at the conference, and it does not seem likely that the science of cybernetics, under the present management, will attempt to deal with such uncomfortable problems. For, in the present volume, under this delightful new name, those social sciences which seemed to have been squeezed to the last anecdote are given a new lease of life.   C. D. DARLINGTON

A BIOLOGICAL DICTIONARY

A Dictionary of Scientific Terms: Pronunciation, derivation, and definition of terms in Biology, Botany, Zoology, Anatomy, Cytology, Genetics, Embryology, Physiology, *by I. F. Henderson and W. D. Henderson; fifth edition by J. H. Kenneth. Pp. xvi + 506. Oliver and Boyd Limited, Edinburgh. 1953. 32s. net.*

In compiling a specialized dictionary, the lexicographer is faced with a distinctly difficult problem: not what to put in, but what to leave out. It is a problem requiring nicety of judgement and firmness of decision, and probably no selection of words would satisfy everyone. That the present dictionary, first published in 1920, has now reached its fifth edition is convincing evidence that it has well served its purpose for over a generation. In its latest form, which was prepared by J. H. Kenneth, it contains definitions, pronunciations, and etymologies of more than 13,500 terms, and there do not appear to be any significant omissions—though it is surprising that cybernetics and chromatography are not included.

The pronunciations, though not given in the symbols of the International Phonetic Association, are sufficiently precise for ordinary purposes and are not likely to meet with criticism. The derivations are succinctly expressed, and where Greek or Russian words are mentioned they are transliterated; in certain cases the transliteration of Greek words represents the sound rather than the exact letters of the original. The layout and type are admirably clear, the paper and binding are good, and the volume as a whole is an excellent example of modern book-making. At 32s. it is by no means highly priced.

BIRD PARASITES

Fleas, Flukes, and Cuckoos, A Study of Bird Parasites, *by Miriam Rothschild and Theresa Clay. Pp. xiv + 304, with many illustrations and four maps. Collins, London. 1952. 21s. net.*

It is not possible in a brief space to do justice to this book, which will take its place, in spite of its lack of colour illustrations, as a worthy example of the series to which it belongs. Many readers will not, in fact, lament the absence of coloured plates. To have real value these must be very well done indeed, and the cost of producing really good coloured pictures of animals is nowadays so high that it is doubtful whether they are always worth the cost. Certainly they would add little to a book like this, which deals primarily with the parasites of birds.

Part 1 of the book deals with the nature of parasites, their origin and evolution, their effects on their hosts, and the effects of parasitism on the parasites. Part 2 is devoted to the fleas and lice of birds, and Part 3 to other parasites, such as protozoa, worms, insects other than lice, mites,

and micro-parasites, with chapters on the fauna of birds' nests, skuas, and the European cuckoo. An appendix gives a useful bibliography. Indices of popular and scientific names, and of the scientific names of the birds mentioned in the text, add to the value of this entertaining and original presentation of a fascinating subject.

No one has yet explained satisfactorily why so many people shudder at the thought or mention of parasites. For those who find them distasteful this book is to be recommended. Its beautiful photographs and lively style reveal throughout not only the authors' wide experience, great learning, and devotion to science, but also their ability to integrate their biological knowledge with the rest of life. No bird-lover should miss this book, and naturalists will welcome it everywhere.

G. LAPAGE

ORIGIN OF COMETS

The Comets and their Origin, *by R. A. Lyttleton. Pp. x + 173, with plates and figures. Cambridge University Press, London. 1953. 25s. net.*

The origin of comets has long been a major problem in astronomy. No instance is known of a comet having entered the solar system from outer space; on the other hand, planetary perturbations not infrequently change the path of a comet to such an extent that it is permanently lost from the system, while from time to time comets have been observed to disintegrate.

In this volume, the available information about the dynamical and physical properties of comets is summarized. The problem of the origin and formation of comets is then discussed. It is supposed that the Sun is moving through one of the galactic dust clouds and that the gravitational attraction of the Sun on the dust particles causes an accretion of the material. Under suitable conditions, aggregations of dust particles, moving in almost parabolic orbits around the Sun, may be formed. These aggregations, it is suggested, give rise to comets. The process is a continuous one, so that the supply of comets is maintained.

The theory is ingenious and plausible. It is based, however, on the assumption of conditions that are idealized and somewhat special, which may differ appreciably from those that actually occur. Other theories of the nature and origin of comets have been developed in recent years; Dr Lyttleton's purpose

has been primarily to expound his own views, but some critical discussion of alternative theories would have enhanced the value of this book.

H. SPENCER JONES

THE NATURE AND RELATIONSHIPS OF GENETICS

General Genetics, *by A. M. Srb and R. D. Owen. Pp. x + 561, with half-tone and line illustrations. W. H. Freeman and Company, San Francisco; Bailey Bros. and Swinfen Limited, London. 1952. 47s. net.*

Drs Srb and Owen set themselves the task not only of presenting the principles of genetics but of displaying the relations which genetical science bears to other branches of biology. Roughly speaking, the first thirteen chapters are devoted to the basic principles of genetics itself, while the remaining eleven cover the genetical aspects of such diverse subjects as sexuality and sex determination, cellular biochemistry, development, population studies, evolution, plant and animal improvement, and human welfare. Included in these latter chapters are also discussions of certain more advanced genetical topics, notably the genetics of continuous variation (or quantitative inheritance as the authors call it), and the effects of inbreeding and selection.

The standard of the first part of the book is high, except for the account of chromosome behaviour, which is descriptive where it should be analytical and is not as well illustrated as it might have been. The authors' success in the latter part of the book is more mixed. Most of the chapters are well suited to introduce the student to the subjects under discussion, and indeed some of them, such as the chapter on cellular biochemistry, are very good: they would make profitable reading for a wider circle than the students at whom the book is aimed. Others, however, are less satisfactory. The accounts of continuous variation and the genetical aspects of development, for example, will hardly give the student a picture of the success which genetics is now achieving in understanding these phenomena.

Even though some portions of the book should be used with caution, a teacher prepared to guide his students' reading will find much of value in it. It is made the more useful by the brief summaries of important features and implications with which the chapters conclude, and by the lists of problems and further reading which are appen-

ded to them. Departments concerned with the teaching of genetics should find a place on their shelves for this book. K. MATHER

PHARMACOPOEIAS

The British Pharmacopoeia 1953. *Pp. xxiv + 894. Published for the General Medical Council by the Pharmaceutical Press, London. 1953. 50s. net.*
The Extra Pharmacopoeia (Martindale), Vol. 1 (23rd edition). *Pp. xxii + 1352. The Pharmaceutical Press, London. 1952. 55s. net.*

The General Medical Council has been responsible for publication of the British Pharmacopoeia since 1858, and this is the eighth edition which has appeared. It became effective on 1st September 1953. The fact that the work now appears at five-yearly intervals, within which an addendum is published, is a striking measure of the rate of progress in medicine and in chemical and biological methods. So large and complex a work cannot be analysed in detail in the space here available, and it must suffice to say that in the main it follows the pattern of its predecessor, and to note a few of the more important changes made. Of these perhaps the most notable, though more by its implications than by its practical consequences, is the abandonment of Latin in the main titles of the monographs. Although this was a change perhaps sooner or later inevitable, there will be not a few who will note it with regret. How much more sonorous and impressive, for example, is '*unguentum emulsificans aquosum*' than 'simple cream.' Latin titles are relegated to second place in reprinting monographs from the 1948 edition, and omitted altogether from new ones. An interesting feature is the increasing importance attached to biology; biological products discussed now include B.C.G. vaccine, scarlet fever antitoxin, and Dick Test toxin. Only a biological method is now given for the assay of vitamin D, but conversely vitamin A is to be assayed spectrophotometrically and not biologically. Among monographs on substances of general scientific interest are those on dimethyl-phthalate, folic acid, gamma benzene hexachloride, and testosterone. A monograph on sterilized surgical catgut is another new departure. Monographs incorporated from the 1951 addendum include proguanil hydrochloride (Paludrine), propyl-thiouracil, and streptomycin hydrochloride.

The Extra Pharmacopoeia was first produced by William Martindale in 1883 to supplement for medical practitioners information contained in the first British Pharmacopoeia which had appeared sixteen years previously. In the seventy years which have since elapsed it has quadrupled in size and become a recognized independent work of exceptional scope, offering authoritative information on medical and pharmacological developments throughout the world. So much new material has accumulated since the last edition appeared eleven years ago that, in order to avoid an unduly bulky volume, closer type-setting has been necessary; even so, the result is far removed from Martindale's original slim and pocketable volume. Of essentially novel material may be mentioned the sections, occupying nearly an eighth of the whole book, on antibiotics, antihistamines, hormones of the adrenal cortex, and muscle relaxants of the curare type. Of historical interest is the incorporation of the defunct 'Squire's Companion' to the British Pharmacopoeia, the copyright of which was acquired by the Pharmaceutical Society of Great Britain in 1948. The book is an astonishing mine of information, made readily accessible by a comprehensive index.

SHAPE AND COLOUR IN ANIMALS

Animal Forms and Patterns, by Adolf Portmann, translated by Hella Czech, illustrated by Sabine Baur. Pp. 246, with line illustrations. Faber and Faber Limited, London. 1952. 25s. net.

In this book Dr Portmann considers the shapes, the coloration, and the colour patterns of animals. He does not deny the importance of present-day research methods, with their emphasis on microscopic or ultramicroscopic characteristics, but he feels that a great deal is missed by neglecting to pay proper attention to what is visible to the naked eye. He points out how intricate patterns are produced by the combined effects of individual elements developing quite separately, in such structures as the feathers of a peacock's tail or the scales of a butterfly's wing.

Many will agree that in some biological studies we can scarcely see the wood for the trees, and will welcome work that tries to take a wider view. Portmann's descriptions of animal forms and patterns are interesting and in general accurate, but his attempts at explaining them may well be challenged. He is very apt to wander off into ill-defined philosophical considerations, expressed in vague language, so that the reader at times finds it difficult to puzzle out what he is driving at. In particular, his frequent supposition or statement that patterns are designed for specific purposes makes unwarranted assumptions that are at variance with the generally accepted ideas of natural selection acting upon the product of genetic mutation or recombinations during the course of evolution.

The book is illustrated with many attractive and skilful line drawings.

L. HARRISON MATTHEWS

VINYL POLYMERS

Vinyl and Related Polymers, by Calvin E. Schildknecht. Pp. x + 723. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London. 1952. 100s. net.

This book is of the high standard which one would expect from the author, who has that rare gift of combining the erudition and accuracy of the text-book with the readability of a more popular work. Another excellent feature, which is not always present in books written by our friends on the other side of the Atlantic, is the liberal credit given to European workers for their contributions in this field.

Instead of devoting the beginning of this book to explaining in an abstract way the basic principles of polymer science, the author has started with styrene, upon which more academic work has been done than on any other polymer, and has included such a large amount of this fundamental work that it constitutes in itself a text-book of polymer science—which the reader assimilates as the pill coated with the sugar of the practical applications of styrene. The book then deals chapter by chapter with the chemistry and physics, technology, and advantages and limitations of each group of vinyl polymers, including the synthetic rubbers and such substances as N-vinyl pyrrolidone, which was used as a blood substitute. The field in which the reviewer has special knowledge was used as a test, and revealed a most up-to-date appreciation of current progress. Only one criticism, and that an unimportant one, can be levelled at this excellent book, namely the absence of a name index. It is to be hoped this omission will be remedied in the second edition.

W. J. S. NAUNTON

ENZYME RESEARCH

Some Aspects of Enzyme Research, edited by Frank Dickens. British Medical Bulletin, 9 (2), 1953. The British Council, London, 1953. 15s. net.

This is a worthy sequel to the Gowland Hopkins memorial volume of 1948, which dealt with new currents in biochemistry. The field of enzyme research is now so extensive and developing so rapidly that a comprehensive and highly authoritative review such as this is very valuable not only to those having an indirect interest but also to those actively engaged in research. The fact that modern work depends entirely upon the sound foundations laid by earlier workers must not be lost sight of, however, and it is very satisfactory to see that the historical approach has not been neglected.

The scope of this symposium is very wide, including such diverse topics as the pyruvate oxidase system (Sir Rudolph Peters); adaptive enzymes (Sir Cyril Hinshelwood); β-glucuronidase and related enzymes (G. A. Levvy); amino-acid decarboxylases (E. F. Gale); cholinesterases (R. H. S. Thompson); and the action of drugs on enzyme systems (J. H. Quastel). H. A. Krebs contributes an excellent review of progress made during the last decade in the study of energy-change in living organisms.

These studies are of outstanding academic interest but have in addition practical possibilities of the utmost importance, pointing the way to the day when the application of 'chemistry and biochemistry to enzymes will prove powerful enough to establish a therapy based upon logical knowledge of the biochemistry of the cell and so to transform much that constitutes pathology today.'

In these days, when the time necessary for reading original scientific literature tends to become so great as to interfere with research, authoritative and critical reviews such as this are increasingly necessary; in compiling it the editor and contributors have been of notable service to their biochemical colleagues.

Some books received

(Note. Mention of a book on this page does not preclude subsequent review.)

BIOLOGY

Bibliography on the Genetics of Drosophila, Part II, by Irwin H. Herskowitz. Pp. 212. *Commonwealth Agricultural Bureaux, Slough.* 1953. 21s. net.

Endosymbiose der Tiere mit Pflanzlichen Mikroorganismen, by Paul Buchner. Pp. 772. *Verlag Birkhäuser, Basle.* 1953. *Paper covers, S. fcs.* 62.40; *bound, S. fcs.* 66.50 net.

Symposium on Chromosome Breakage, held at the John Innes Horticultural Institution 9–11th June, 1952. Pp. 315. *Oliver and Boyd Limited, London.* 1953. 45s. net.

BOTANY

Dispersal in Fungi, by C. T. Ingold. Pp. 197. *Oxford University Press, London.* 1953. 18s. net.

Flore Analytique des Champignons Supérieurs (Agarics, Bolets, Chanterelles), by Robert Kühner and Henri Romagnesi. Pp. 558. *Masson et Cie., Paris.* 1953. *Paper covers, fcs.* 7010; *bound, fcs.* 7970 net.

New Zealand Pollen Studies: Monocotyledons, by Lucy M. Cranwell. Pp. 91. *Harvard University Press, for Auckland Institute and Museum, New Zealand.* 1953. *Paper covers,* 20s.; *bound,* 30s. net.

Physiology of Seeds, by (the late) William Crocker and Lela V. Barton. Pp. 267. *Chronica Botanica Company, Waltham, Mass.; Wm Dawson and Sons, Limited, London.* 1953. $6.50 net.

CHEMISTRY

Applied Inorganic Analysis, by W. F. Hillebrand and G. E. F. Lundell. Second edition, revised by G. E. F. Lundell, H. A. Bright, and J. I. Hoffmann. Pp. 1034. *John Wiley and Sons, Inc., New York; Chapman and Hall Limited, London.* 1953. 120s. net.

Chemical Constitution, by J. A. A. Ketelaar. Pp. 398. *Elsevier Publishing Company, Amsterdam; Cleaver-Hume Press Limited, London.* 1953. 40s. net.

Chemistry of Carbon Compounds, Vol. II, Part A. Alicyclic Compounds, edited by E. H. Rodd. Pp. 487. *Elsevier Publishing Company, Amsterdam; Cleaver-Hume Press Limited, London.* 1953. 84s. net.

Encyclopedia of Chemical Reactions, Vol. V, edited by C. A. Jacobson. Pp.

787. *Reinhold Publishing Corporation, New York; Chapman and Hall Limited, London.* 1953. 120s. net.

Estimation of Organic Compounds, by F. Wild. Pp. 239. *Cambridge University Press, London.* 1953. 25s. net.

Non-Aqueous Solvents, by Ludwig F. Audrieth and Jacob Kleinberg. Pp. 284. *John Wiley and Sons, Inc., New York; Chapman and Hall Limited, London.* 1953. 54s. net.

Synthetic Organic Chemistry, by Romeo B. Wagner and Harry D. Zook. Pp. 887. *John Wiley and Sons, Inc., New York; Chapman and Hall Limited, London.* 1953. 92s. net.

Textbook of Quantitative Inorganic Analysis, by I. M. Kolthoff and E. B. Sandell. Pp. 759. *The Macmillan Company, New York.* 1953. $6.50 ($5.00 outside U.S.).

GENERAL

The Earth and Its Mysteries, by G. W. Tyrrell. Pp. 278. *G. Bell and Sons Limited, London.* 1953. 16s. net.

Lectures on Atomic Energy Industrial and Legal Problems, delivered at University of Michigan Law School, June 26 – June 28, 1952. Pp. 280. *Michigan University Press, Michigan; Geoffrey Cumberlege, London.* 1952. 40s. net.

Un Maître de l'Enquête Scientifique— Louis Pasteur, by Jacques Nicolle. Pp. 222. *La Colombe, Paris.* 1953. Fcs. 610 net.

MEDICINE

The Harvey Lectures 1951–1952. Series XLVII. Pp. 271. *Academic Press Inc., New York; Academic Books Limited, London.* 1953. 60s. net.

Immunochemistry: A Symposium held at the London School of Hygiene and Tropical Medicine on 15th November 1952, edited by R. T. Williams. Pp. 94. *Cambridge University Press, London.* 1953. 12s. 6d. net.

Las investigaciones sobre inmunidad, by R. Doerr. Pp. 1170 *in all; in five volumes, which may be purchased separately. Revista de Occidente, Madrid.* 1952–3. *Pesetas* 270 *for the* 5 *volumes.*

The Living Brain, by W. Grey Walter. Pp. 216. *Gerald Duckworth and Company Limited, London.* 1953. 15s. net.

Toxicity of Industrial Organic Solvents (rev. ed.), by Ethel Browning. Pp. 411. *Her Majesty's Stationery Office, London.* 1953. 35s. net.

PHYSICS

Dislocations and Plastic Flow in Crystals, by A. H. Cottrell. Pp. 223. *Oxford University Press, London.* 1953. 25s. net.

Electron Optics, by O. Klemperer. Pp. 471. *Cambridge University Press, London.* 1953. 50s. net.

Experimental Nuclear Physics, Vol. I, edited by E. Segrè. Pp. 789. *John Wiley and Sons, Inc., New York; Chapman and Hall Limited, London.* 1953. 120s. net.

Flames: Their Structure, Radiation and Temperature, by A. G. Gaydon and H. G. Wolfhard. Pp. 340. *Chapman and Hall Limited, London.* 1953. 55s. net.

Lecture Notes on the Use of the Microscope, by R. Barer. Pp. 76. *Blackwell Scientific Publications, Oxford.* 1953. 6s. net.

Luminescence and the Scintillation Counter, by S. C. Curran. Pp. 219. *Butterworths Scientific Publications, London.* 1953. 32s. 6d. net.

The Magnetic Circuit, by A. E. de Barr. Pp. 63. *The Institute of Physics, London.* 1953. 5s. net.

Modern Mass Spectrometry, by G. P. Bernard. Pp. 326. *The Institute of Physics, London.* 1953. 50s. net.

Radioactive Isotopes, by W. J. Whitehouse and J. L. Putman. Pp. 424. *Oxford University Press, London.* 1953. 50s. net.

Radioisotopes in Industry, edited by John R. Bradford. Pp. 309. *Reinhold Publishing Corporation, New York; Chapman and Hall Limited, London.* 1953. 64s. net.

The Stability of Rotating Liquid Masses, by R. A. Lyttleton. Pp. 150. *Cambridge University Press, London.* 1953. 35s. net.

ZOOLOGY

Social Behaviour in Animals, by N. Tinbergen. Pp. 150. *Methuen and Company Limited, London; John Wiley and Sons, Inc., New York.* 1953. 12s. 6d. net.

Traité de Zoologie. Anatomie, Systématique, Biologie. Vol. I, Part II— Protozoaires: Rhizopodes, Actinopodes, Sporozoaires, Cnidosporidies, edited by Pierre-P. Grassé. Pp. 1160. *Masson et Cie., Paris.* 1953. *Paper covers, fcs.* 9215; *bound, fcs.* 9935.

Notes on contributors

FREDERICK CHALLENGER,
D.Sc., Ph.D., F.R.I.C.,

Was born in 1887 and was educated at Ashville College, Harrogate. Studied chemistry at Derby Technical College under Jamieson Walker (1904–7). Worked with Kipping on organo-derivatives of silicon at University College, Nottingham (1908–10), and then, as 1851 Exhibition Scholar, with Wallach in Göttingen on derivatives of thujone. Lecturer in chemistry in the University of Birmingham under Frankland and Morgan (1912–20), Senior Lecturer in the University of Manchester under Dixon, Lapworth, and Robinson (1920–30). From 1930 to 1953 was professor of organic chemistry in the University of Leeds. Published researches have dealt with organo-derivatives of bismuth, thallium, and boron; with orientation in aromatic compounds; and with heterocyclic compounds of sulphur. Work on methylation processes in mould cultures led to study of occurrence of methylated compounds of sulphur in nature. Senior Gas Adviser N.E. Region (1939–45). Member of Councils of the Chemical Society (1934–7) and of the Royal Institute of Chemistry (Vice-President 1948–51).

F. W. GIBBS,
M.Sc., Ph.D., F.R.I.C.,

Was born in 1913 at Chelsea, and was educated at Hitchin Grammar School, University College, London (Departments of Chemistry and of History and Philosophy of Science), and Institute of Education. Was a teacher of chemistry until joining the Army in 1940, being commissioned in the Royal Corps of Signals in 1941. After the war taught in a Middlesex grammar school (1946–9), and then became a specialist science officer with the British Council (1950–1). Is now Assistant Secretary and Editor, Royal Institute of Chemistry. Is author of several papers on the history of chemistry and technology, published mainly in 'Annals of Science.'

J. BERLIOZ,
Docteur en Pharmacie,

For several years studied simultaneously in the faculties of science and of pharmacology, Paris, and at the *Muséum National d'Histoire Naturelle.* In 1920 was appointed assistant in the department of mammals and birds at the *Muséum,* subsequently becoming curator-in-chief and then director. Is interested in all problems relating to ornithology and biogeography, but particularly in the *Trochilidae.*

M. W. CHIPLONKAR,
M.Sc., D.Sc.,

Was born in 1909 at Poona. He was educated at the Fergusson College, Poona, and the Benares Hindu University. Obtained the Doctorate of Science (physics) of the University of Bombay in 1942, and in 1943 was awarded the Moos Medal, the highest honour of that university, for a thesis on the physics of the upper atmosphere. Has served in the S.P. College, Poona, as a professor of physics, as professor in charge of the school of radio physics and electronics, Poona, and also as a recognized university teacher for postgraduate teaching and research in physics, Bombay University. Later served for some time as meteorologist in the India Meteorological Department at Poona and Calcutta. At present is head of the department of physics, Poona University. Is the author of several original papers on geophysics and meteorology.

CHARLES SINGER,
M.D., D.Litt., Hon. D.Sc., F.R.C.P.,

Was born in London in 1876 and studied at University College, London, Magdalen College, Oxford (of which he is now an Honorary Fellow), and Heidelberg. He has been lecturer in the history of biology at Oxford, professor of the history of medicine at London University, and visiting professor of the

history of science at the University of California. He has written widely on the history of science and medicine. Among his works are 'A History of Biology,' a 'Short History of Science' and 'The Earliest Chemical Industry.' With E. J. Holmyard and A. R. Hall he is editing 'A History of Technology' in five volumes. Much of his work has been done in collaboration with his wife, Dorothea Waley Singer, who is known for her writings on the philosophy of science, on alchemy, and on the bibliography of early science.

F. L. C. BARANYOVITS,
B.Sc., D.Sc.,

Was born in Hungary in 1908 and graduated at the University for Agricultural Sciences, Budapest. After a short period in Vienna he returned to Budapest to take his doctorate and then for twelve years pursued entomological research, principally in the field of plant protection, at the University Institute for Plant Pathology and in the Royal Hungarian Institute for Plant Protection Research. In 1944 he left Hungary and made his way to Switzerland, where he entered the service of the Geigy Company, pursuing further researches on the control of agricultural pests. In 1949 he joined the staff of the Hawthorndale laboratory of Imperial Chemical Industries Limited, specializing in the study of scale insects and their control.

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